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A magnesian chamosite from the Wenlock Limestone of Wickwar, Gloucestershire.

(With Plates VIII and IX.)

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[Read March 22, 1945.]

General description (W.F.W.).

THE Little Avon river rises on the scarp slope of the Cotswolds near Hawkesbury, 14 miles north-east of Bristol, and flows in a westerly direction ver Mesozoic strata, until half a mile south-east of Wickwar it cuts through ne Triassic mantle and exposes to view three inliers of Wenlock Limestone Whittard & Smith, 1944, p. 65 and map). The West Gloucestershire Water ompany was interested in the valley as a possible site for an impounded reservoir, nd as part of a preliminary survey a trial-shaft was sunk into the Wenlock imestone of the southernmost inlier situated near Sturt Bridge. The shaft enetrated 28 feet of dolomitized siltstones and crinoidal limestones, and at a epth of 4 feet it entered a band of calcareous chamositic siltstone averaging inches in thickness. The shaft had been completed and the sides boarded before e heard it had been sunk; the hand-specimens were therefore obtained from ne tip-heaps, but there is no doubt that all the material originated from the me horizon.

The chamositic bed rests upon dolomitized crinoidal limestone; in some places e latter was partly dried and cracked, possibly through exposure in the littoral ne, before the chamositic silt formed and infilled the cracks. The contact tween the two rocks is generally sharply defined and suggests a period of n-deposition which, however, was of too short duration to be described as a n-sequence. In other examples the contact is less definite because the lower o or three inches of the chamositic bed include many pieces of dolomitized e-grained limestone, numerous crinoid ossicles, and derived colonies of *Favosites* d *Halysites*. The limestone fragments are not crinoidal; they are characteristi-lly bent, internally contorted, and frequently exhibit re-entrant angles (pl. VIII).

Such structures indicate that somewhere near at hand a plastic calcareous m was comminuted and incorporated in the chamositic silt; elsewhere entom colonies of corals were uncovered, and crinoid ossicles were separated and c centrated by aqueous action from a calcareous mud rich in fossil remains. T rock is thus an example of an intraformational breccia; Hayes (1915, p. pl. X) has described a similar rock from the Wabana iron ore. Agitated sea-wa may have eroded the calcareous mud; alternatively, the incidence of a profoun different chemical environment in which the chamosite was formed may ha resulted in acidity variations in the sea-water, which induced convection curre and these caused the break-up of the plastic mud.

The calcareous chamositic siltstone is green in hand-specimen and ca innumerable, almost black, shiny ooliths which show a crude bedding. Mic scopically,[1] the ooliths of chamosite are well formed, exhibit none of the spa lithic shapes described from the Dogger of Yorkshire (Rastall & Heming 1940, p. 265), and there are no clastic ooliths indicating redeposition; they usually flattened, sometimes globular or irregular in form, and range from 0·2 m to 0·5 mm. in length (pl. IX, figs. 1, 2). The fresh mineral presents a rich gre colour; it is markedly pleochroic, being greenish-yellow for rays vibrating para to the oolitic layers, which possess positive elongation, and grass green for ra vibrating at right angles; the refractive index is $1{\cdot}620 \pm 0{\cdot}002$ (Na) and the spec gravity[2] 3·034; these figures compare with 1·63 and 3·14, and 1·665 and 3· determined for the more ferriferous chamosites described by Deans (1934, p. from the Coal Measures of Cottingley Beck, west Yorkshire and by Hallimo (1939, p. 445) from the Frodingham ironstone of Lincolnshire. The chamos loses its strong green colour when weathered, becomes brown, and eventua breaks down into limonite. The smooth concentric layers of the ooliths a emphasized by dark dust, mainly composed of rutile (?), which is concentrat into impersistent tenuous bands (pl. IX, fig. 3); a nucleus invariably occurs a may consist of subangular or angular calcite, a fragment of a crinoid ossicle a microfossil, finely divided reddish-brown limonitic dust, or finely divid rutile (?) dust which is frequently associated with platy chamosite. The mine is also present in microfossils and is developed as a muddy infilling to shells which the shell substance has also been replaced by chamosite; the fossils, whi are probably derived, include minute spirally coiled gastropods and also ostraco nearly related to *Beyrichia* and *Leperditia*.

The groundmass is composed of two distinct but intermingled rock-types. chamositic siltstone and a calcareous mudstone (pl. IX, fig. 4). The siltsto contains most of the ooliths, for these are relatively scarce in the mudstone, a it consists of innumerable small flakes of chamosite, clastic quartz up to 25 across, occasional rhombohedra of dolomite, and minute flakes of colourl minerals; the last, in cross-section, show straight extinction and positive elong tion and are probably a mica, but those examples with lower birefringence m perhaps be kaolinite. The calcareous mudstone contains some calcite, but it

[1] The rock is friable and difficult to section; the best results were obtained by completi the grinding of the sections with 3F carborundum mixed in propylene glycol. The latter used without dilution; it is a hygroscopic alcohol, miscible in water, and reduces the teari action on the section during grinding.

[2] Determined with Clerici solution and refractometer, corrected to 21° C.

mposed mainly of dolomite and ankerite (pl. IX, fig. 5); chalybite is much less mmonly developed as demonstrated by the hydrogen peroxide test (Hallimond, 25, p. 39).

The chamosite is remarkably fresh and clear-coloured when the age of the posit is taken into account. The Silurian rocks have obviously only recently en cleared of part of their Triassic mantle and had remained covered since e Triassic sediments were laid over them. The freshness and the high magnesia ntent of the chamosite may be attributed to the action of saline solutions ich during Triassic times heavily dolomitized the Wenlock Limestone (Whittard Smith, 1944, p. 73). That solutions rich in magnesium salts had direct access the chamositic siltstone is clearly indicated in thin-sections where dolomite common in the matrix, and in hand-specimens where cracks up to $\frac{3}{4}$ inch wide e now infilled by heavily dolomitized sediment of Triassic age which encloses all fragments of red and green Keuper Marl.

Occurring sporadically throughout all the slides, and particularly in the amositic siltstone as distinct from the calcareous matrix, are spheroliths which n definitely be identified as phosphatic calculi or 'pearls' developed in polyzoa . IX, figs. 6, 7). Oakley (1934, p. 296) determined their true nature and com-sition although other investigators, notably Sollas (1879, p. 501), had directed tention to their occurrence. The calculi are spherical to irregularly rounded shape, of uniform size ranging from 0·3 mm. to 0·4 mm., white to yellowish-own in colour, and exhibit a pearly lustre. In thin-sections they are usually lourless but may be yellow, possess a positive elongation in a direction parallel the concentrically arranged layers, and under crossed nicols show a dark cross d a bluish-grey polarization colour; the refractive index is 1·605. The calculi ervesce in dilute hydrochloric acid, but not in 30 % acetic acid, as Mrs. Knight 937, p. 5) ascertained when she investigated some of the limestones of Silurian e developed in the Malvern and west Midland outcrops; by using this strength acetic acid she was able to isolate the calculi which occurred in the limestones tached from the parent polyzoa. The Wickwar calculi were hand-picked from heavy mineral fraction separated from the crushed rock by the use of bromo-rm. According to Oakley the calculi are composed of dahllite, an apatite con-ning about 10 % of calcium carbonate. X-ray photographs of single pearls m Wickwar yielded weak powder patterns characteristic of apatite, but the akness of the pattern may be due to the presence of some less well crystallized terial.

Chemical and X-ray studies (*F.A.B.*).

In order to isolate ooliths for chemical and X-ray examination the siltstone s crushed and passed through sieves; the 60- and 40-mesh samples were placed bromoform slightly diluted with benzene and the heavy fraction separated. is was hand-picked under a binocular microscope and a concentrate of chamo-ic ooliths selected for chemical analysis. In the first instance the chemical ocedure followed was that of Ennos and Sutcliffe (1925, p. 115), although it s found necessary to boil the powdered ooliths in hydrochloric acid for five nutes. Appreciable quantities of copper and zinc were afterwards reported a qualitative spectroscopic analysis, and a partial analysis was commissioned determine the amounts of these constituents. Determinations of the total ter content by the Penfield method and also of the water lost below 105° C.

were carried out on separate portions of the ooliths. The chemical analysi the acid soluble portion of the mineral is given in table I.

TABLE I. Chemical analysis of magnesian chamosite, Wickwar, Gloucestershire.

	I.	II.	III.		I.	II.	I
SiO_2	20·35	26·40	24·9	P_2O_5	0·85	—	-
Al_2O_3	14·05	18·23	15·6	CO_2	2·12	—	-
Fe_2O_3	4·40	5·70	7·2	SO_3	nil	—	-
FeO	19·94	25·87	35·0	Na_2O	0·13	0·17	-
MnO	0·03	0·04	0·4	K_2O	0·13	0·17	-
MgO	8·75	11·35	4·6	Insoluble ...	15·66	—	-
CaO	4·14	0·42	—	H_2O- ...	n.d.	1·05	-
TiO_2	0·08	—	—	H_2O+ ...	n.d.	10·60	[1
					90·63	100·00	10

I. Chemical analysis by Geochemical Laboratories of 2·9 grams hand-picked oo Wickwar, Gloucestershire. B.M. 1945,45. The sample was examined by methods similar to t adopted by Ennos and Sutcliffe (1925, p. 115). The acid extract was prepared by a 150 ml. N/2 HCl to 0·7 gm. of rock powder, raising to boiling point in a period of 5 min and then boiling for 5 minutes and allowing to cool for a further 20 minutes. The solution filtered and the residue re-extracted in the same manner with 50 ml. N/2 HCl. The acid extracts were combined and analysed. The insoluble residue was treated with Na_2CO_3 solution and the silica so dissolved added to that in the acid extracts. In the cas the ferrous iron determination the extractions were made as described above, but omi the Na_2CO_3 treatment, and the whole operation was carried out in an atmosphere of car dioxide. The ferric iron in this solution was rapidly titrated with titanous chloride i atmosphere of carbon dioxide and the ferrous iron obtained by difference.

A further portion of 1 gm. was treated as above and the filtrate extracted with dithizo This extract was shaken with dilute HCl to remove zinc and copper determined with sod diethyl-dithio-carbonate; CuO 0·002 %. Zinc could not be detected in the aqueous ext and is certainly less than 0·005 %.

II. The total water content of a separate portion of hand-picked ooliths was obtained heating ½ gm. in a Penfield tube to a red heat and weighing the condensed water vapour. figure obtained was 11·65 %. Another portion of ½ gm. lost 1·05 % in weight when hea to 105° C. for 2 hours (F. A. Bannister). The partial analysis of column I was then recalcula omitting the insoluble residue, the phosphate and carbonate as dahllite and calcite, and titania as rutile.

III. Chemical analysis by C. O. Harvey of chamosite from Frodingham, Lincolnsh recalculated to 100 %. (Hallimond, 1939, p. 445.)

Unfortunately the insoluble residue, amounting to 15·66 %, has not b retained for study, and it was decided to prepare a fresh sample of the resi for thorough examination. Accordingly, ½ gm. finely powdered ooliths treated with hydrochloric acid and the silica set free removed with sodi carbonate solution following the procedure of Ennos and Sutcliffe. This tre ment, however, is not always successful in completely decomposing the chlor Dixon found (1930, p. 99), in his analyses of chamositic mudstone from Ayrsh that the times specified for acid treatment were insufficient; and Pulfrey (19 p. 421) obtained a residue of 12 % from a chlorite from Llandegai, North Wa which completely dissolved when the times were doubled and the reaction carr out just below boiling point. In the experiment now being described, the weig residue after filtering, washing, and drying was 50 %, and the change fro green to a buff tint of the powdered chamosite was not complete. According the modified treatment adopted in the chemical analysis by the Geochemi Laboratories was repeated on the residue. Instead of carrying out the a reactions and silica solution in sodium carbonate on a steam-bath, the acid a

kali solutions were boiled. Further attack on the chamosite residue took place nd the green colour of the powdered ooliths disappeared. The weighed residue fter both treatments was only 5·94 %, and yielded an X-ray powder photograph owing quartz as the dominant constituent. Having evaporated the supernatant spension, obtained by shaking the residue with water, a second powder photo- raph showed that all the quartz had been removed and that the dispersed rticles were chiefly rutile. This determination was confirmed by Dr. M. H. Hey, ho reported much titanium present in a portion of the residue used for X-ray camination. Little difficulty was experienced in determining the quartz in the sidue with the polarizing microscope, but rutile particles could not be recognized, robably because of their smaller size. No constituent in addition to rutile and uartz was determined with certainty, although one or two weak diffraction nes on the powder photographs remain unexplained. Hence the maximum ntent of quartz and rutile in the magnesian chamosite is 5·94 %.

We are now left with nearly 10 % of residue in the chemical analysis (table I) naccounted for. So far as our experiments are concerned, and those of other orkers who obtained a variable amount of residue when they varied the pro- dure of acid solution, this residue in addition to quartz and rutile was made up residual chamosite. It has become apparent during the present work that the id solution method is a valuable adjunct to a more direct method of chemical nalysis, since it concentrates accessory minerals insoluble in acid in a form itable for X-ray, spectrographic, and chemical examination. Direct analysis, cluding a proper determination of the water is, however, essential, particularly hen, as in the present instance, the ooliths have been picked free from matrix nd the principal accessory minerals successfully determined.

Hallimond decided from his study of the chemical composition of minerals the chlorite family that chamosite cannot be distinguished solely by chemical nalysis from iron-rich chlorites like daphnite, but that 'additional tests especially y X-ray and solubility' are 'essential for complete identification' (1939, p. 451). have shown in an appendix to Hallimond's paper (p. 459) that X-ray photo- aphs of chamosite are indeed diagnostic and serve to distinguish them from her members of the chlorite group. With this work in mind the present study as suggested. A few of the dark-green ooliths, hand-picked from the Wickwar tstone for chemical analysis, were reserved for optical examination and X-ray udy. These had been broken and wherever possible the nucleus was removed. -ray rotation photographs of single oolith fragments from this sample were st taken, and the only visible differences in pattern revealed were due to the esence of a trace of relatively coarse-grained quartz in some of the ooliths. his mineral when present yielded only one very weak flecked diffraction line 3·35 Å. Recent unpublished work by Dr. M. H. Hey and one of the authors a bauxite, found to contain 2 % free silica as quartz, suggests that none of e single ooliths from Wickwar contains more than 5 % quartz and that the ajority contain less. A powder photograph of a few ooliths and another tained at a later date from a larger sample both yielded the same pattern as e individual oolith fragments, with a certain loss of definition of the weaker es due to powdering. The single ooliths also yield, when suitably mounted on e X-ray goniometer, powder photographs with enhancement of the intensities the lines due to the basal diffractions. A single oolith is therefore an aggregate

of tiny flakes mostly lying tangential to the surface. This effect of orientat of the individual flakes parallel to the surface of the ooliths is diminished photographs of powdered ooliths. With due allowance for this orientation ef and the variability of the trace of quartz present, all the photographs of Wickwar ooliths yield the same powder pattern of chlorite type with a str basal reflection at 14 Å.

The pattern can be distinguished from that of iron-rich chamosite fr Frodingham (pl. VIII, figs. 2 and 3), and it is also different from all chlorite have so far examined, although it resembles that of diabantite (pl. VIII, fig. a chlorite containing a high percentage of magnesium as well as ferrous ir The powder data, given in table II, reveal those differences in pattern which

TABLE II. Powder data for magnesian chamosite.

	1.	2.	3.	4.
002	14 s	—	— m	15 Å. vs
004	7·1 vs	7·1 vs	6·93 vs	7·15 s
006	4·73 w	—	—	4·80 w
	4·69 ms	4·63 m	4·63 m	4·62 m
008	3·53 vs	3·53 s	3·50 s	3·58 ms
	—	—	—	3·04 mw
	2·83 m	—	2·779 mw	2·87 vw
	2·69 w	2·69 ms	2·689 vw	2·66 m
	2·61 w	—	—	—
	2·60 vw	—	—	2·60 m
	2·52 vw	2·53 ms	2·507 ms	2·53 m
	2·46 mw	2·47 mw	—	2·47 m
	2·39 mw	2·40 mw	—	2·40 w
	2·28 w	—	2·330 vvw	2·29 vw
	2·14 vw	2·16 w	2·134 mw	2·145 vw
	2·08 vw	—	—	—
	2·01 m	2·02 vw	—	2·02 vw
	1·89 w	—	—	1·90 vw
	1·83 vw	1·78 vw	1·767 w	—
	1·72 w	1·72 w	—	1·70
	1·67 w	1·68 w	—	—
	1·63 vw	—	—	—
	1·573 mw	—	—	—
060	1·552 ms	1·557 s	1·556 m	1·545
	1·517 m	1·524 ms	1·524 w	1·518
	1·479 vw	—	1·473 vw	—
	1·424 m	1·427 m	1·425 vw	1·427
	1·395 m	—	—	—
	1·361 vw	1·350 w	—	—
	1·333 vw	1·328 w	—	1·331
	1·301 vw	1·303 w	—	1·303
	1·228 vw	—	—	—
	1·183 w	—	—	—
	1·136 vw	—	—	—
	1·104 vw	—	—	—
	1·047 m	1·052 m	—	1·053
	1·014 w	1·020 w	—	—

1. Magnesian chamosite, Wickwar, Gloucestershire; B.M. 1944,45. a 5·37, b 9·31, c^* 28·24 (pl. VIII, fig. 3).

2. Chamosite, Frodingham, Lincolnshire. a 5·39, b 9·34, c^* 28·24 Å. (pl. VIII, fig. 2).

3. Chamosite, Schmiedefeld, Thuringia; 002 observed but not measured. (Engelhar 1942, p. 148.) a 5·39, b 9·34, c^* 28·00 Å.

4. Diabantite, Connecticut valley, U.S.A.; B.M. 53917. a 5·35, b 9·27, c^* 28·64 Å. (pl. VI fig. 5).

1, 2, and 4 are lists of the spacings in Ångström units and estimated intensities of X-r powder photographs taken with unfiltered iron radiation, λ 1·934 Å., in a cylindrical came diameter 6 cm. Under 3 are listed von Engelhardt's measurements using iron radiati filtered with manganese, camera diameter 5·75 cm. $c^* = c \sin \beta$ is the basal spacing.

not so readily apparent on the reproduced photographs. The mode of occurren and physical properties relate the Wickwar mineral more closely to chamosi than any other chlorite, whilst the partial chemical analysis shows that it diffe from chamosites previously studied in possessing a much higher percentage magnesium. The higher magnesium content is related to the lower specif gravity and refractive index and probably accounts for the difference in X-ra patterns. Although the chemical technique employed is not beyond criticism we consider that the partial chemical analysis is sufficiently accurate to show th the Wickwar mineral is the first magnesium-rich chamosite to be described, a suggest that it should be referred to as a magnesian chamosite.

The only lines on the powder photographs of chamosite which can be indexe with certainty are the basal diffractions 00l and the diffraction 060 (see table I McMurchy (1934, p. 427), using a powder camera with larger diameter (11·46 cm.

s able to index all the diffractions from sheridanite and then obtained good reement between the observed intensities and those calculated on the assumpn of Pauling's crystal-structure (1934, p. 580). Engelhardt (1942, p. 148) has en powder data for chamosite from Schmiedefeld using material previously udied by Jung (1931, p. 281), and his results obtained with filtered iron radiation a camera 5·75 cm. diameter are also given for comparison in table II. It is parent that his values are close to those for Frodingham material. He has empted to index the observed diffractions, utilizing McMurchy's for sheridanite, t found that it was necessary to make β 90°, i.e. to use a unit cell of orthombic dimensions. He has then deduced a structure related to that of chlorite. attempt to index the observed diffractions of magnesian chamosite by utilizing Murchy's data and Engelhardt's assumption that β is 90° has not been success-. the number of possible indices for all lines other than those readily assigned basal diffractions and 060 being high even for lines close to the centre of the n. It is difficult to see how any reliance can be placed upon indexing of the fractions of general type *hkl* of a substance of orthorhombic or lower symmetry rely from a powder photograph taken in a small camera. Unless this can be ue unequivocally, little progress can be made towards a more detailed study the crystal-structure of magnesian chamosite. The relative intensities of the lines, however, do show a correspondence with McMurchy's data, i.e. with rease in iron content 004 and 008 increase in intensity relative to 002, 006, l 0.0.10 (see table II). This at least suggests that the sequence of layers is ilar in chamosite to those in Pauling's structure of chlorite, and that the lacement of magnesium by iron alters the relative intensities of the basal fractions in a similar manner.

It is important in X-ray work on fine-grained sedimentary minerals to be sure ut minor constituents are not overlooked. Owing to an intimate mixing of such nerals during deposition, physical separation is not always possible and even croscopic examination sometimes fails. The evidence must then be sought by ray methods. The orientation of chamosite flakes in the individual ooliths uld also be probably accompanied by similar parallel alinement of flakes of y other mineral with a layer structure that may be present. The sensitivity the X-ray method can be greatly increased for the determination of layer-ucture minerals if an orientated aggregate of a fine-grained mineral sample prepared. Accordingly, a few magnesian chamosite ooliths were crushed and posited from a benzene suspension upon a thin film of cellulose acetate lying a surface of water. The film was then mounted with its plane vertical and illation and rotation photographs taken. These showed enhanced basal fractions, due to chamosite, of greater intensity than those previously obtained m individual ooliths, but no additional lines could be detected. No member the mica group, therefore, is present in sufficient quantity to be recorded. A er-structure mineral like kaolinite would be very difficult to detect in the sence of chamosite, owing to the coincidence of their strong basal diffractions. is mineral, however, is almost insoluble in N/2 HCl and would have been ected in the residue if present. So far the only accessory minerals that can observed with certainty in the ooliths are quartz and rutile. Of these two, ile would be difficult to detect on the powder photographs of the untreated iths, owing to the closeness of its strong powder-line spacings to those of quartz.

It is probable that most of the quartz found in the residue and all the phosph and carbonate found by analysis are enclosed in the nuclei of the chamosite ooli Some of these nuclei are probably similar to the matrix in composition. In absence of any special study of the mineral composition of the matrix, we s assume that the phosphate and carbonate are present as dahllite and ca These minerals account for 3·82 % of the lime found by analysis and 0·32 % CaO is assumed to be combined in the magnesian chamosite. The s percentage of titania has been neglected on the assumption that it repres rutile dissolved in hydrochloric acid. In table I, therefore, the recalcula analysis omits carbonate, phosphate, and titania. The oxygen percentage t obtained, combined with the specific gravity and probable unit-cell dimen of magnesian chamosite derived from powder data, yields an (O,OH) co of 72·95, in fair agreement with the figure of 72 demanded by Pauling's chl structure.

TABLE III. Dimensions and atomic contents of unit cells of magnesian chamosite, &c

		1.	2.	3.	4.	5.	6.
16	Si	11·32	11·50	11·43	11·69	11·96	12·20
	Al	4·68	4·50	4·57	4·31	4·04	3·80
12	Al	4·53	4·85	3·88	4·33	4·49	4·91
	Fe‴	1·84	—	2·50	—	2·26	—
	Fe″	5·63	7·15	5·62	7·67	5·25	7·09
R	Fe″	3·65	4·14	7·80	8·56	7·66	8·39
	Mg	7·25	7·36	3·13	3·20	2·99	3·05
	Ca	0·19	0·20	—	—	—	—
	Mn	0·01	0·01	0·17	0·18	—	—
	Na	0·14	0·14	—	—	—	—
	K	0·09	0·09	—	—	—	—
	H	30·32	30·78	—	—	—	—
	R	11·33	11·94	11·10	11·94	10·65	11·44
	a (Å.)	5·37	—	5·39	—	5·39	—
	b	9·31	—	9·34	—	9·34	—
	*c**	28·24	—	28·24	—	28·00	—
	Sp. gr.	3·034	—	3·34	—	3·19	—
	n	1·620	—	1·665	—	1·658	—

1. Magnesian chamosite, Wickwar, Gloucestershire; B.M. 1944,45. Atomic contents unit cell calculated from chemical analysis, column 2, table I, excluding H_2O and assumi 72 (O,OH) per unit cell. The actual number of oxygens and hydroxyls calculated fr chemical analysis, unit-cell dimensions, and specific gravity is 72·95.

3. Chamosite, Frodingham, Lincolnshire, calculated from C. O. Harvey's analysis, column table I (Hallimond, 1939, p. 445), assuming 56 oxygen atoms per unit cell.

5. Chamosite, Schmiedefeld, Thuringia, calculated from Jung's analysis (1931, p. 28 assuming 56 oxygen atoms per unit cell.

2, 4, and 6 recalculated from 1, 3, and 5 respectively, assuming that all the iron cont was originally ferrous.

Table III shows that the atomic contents of the unit cell of magnesian chamosi yield a low summation of metal ions. This is true of all available analyses chamosite and also of some other chlorites when they are calculated on a bas of 56 oxygen atoms. Holzner (1938, p. 389), following a suggestion of Winche (1936, p. 642), recalculated various chlorite analyses on the assumption that t ferric content arose from oxidation of the ferrous ions in the crystal-structu subsequent to formation of the mineral. He adduces as evidence the low wat content of such specimens and the summation of the metal ions to 40 per

ygens when all the iron content is reckoned as ferrous. He also recalculated ıer analyses of ferriferous chlorites which possess normal water content and ·ld the ideal summation of 40 metal ions when the ferric content is counted as :h. These chlorites he considers to be unchanged and to have possessed ferric ıs at the time of their formation. There is little doubt that Holzner's assumpns are correct for certain chlorites; the ion summations are too close to 40 to fortuitous. Moreover, it seems likely that fine-grained chamosites might very ll have undergone partial oxidation since their formation. Certainly the :alculation of both the chamosite analyses on Holzner's assumption leads to :ellent agreement with the structural formula for chlorites (see table III). .at chamosites originally contained no ferric, only ferrous, ions is probably ıe, but low ion summations of the recalculated analyses may be explained by ·ors in chemical analysis or admixture of the chamosite with small amounts undetected minerals soluble in acid. Table IV gives the unit cell dimensions

TABLE IV. Unit-cell dimensions and atomic contents of chlorites related in composition to chamosite.

		I.	II.	III.
Si	...	10·82	9·67	13·69
Al	...	5·18	6·33	2·31
Al	...	5·40	3·33	3·06
Fe‴	...	0·71	3·04	0·70
Fe″	...	5·89	5·63	8·24
Mg″	...	—	—	—
Fe″	...	7·59	9·11	0·41
Mg″	...	3·70	2·87	10·13
Ca	...	0·05	—	0·49
Mn	...	0·18	—	0·14
Na	...	—	—	0·20
K	...	—	—	—
R	...	11·52	11·98	11·37

		I.	II.	III.
a	...	5·40	5·37	5·35 Å.
b	...	9·36	9·30	9·27
*c**	...	28·20	28·00	28·64
Sp. gr.	...	3·08	3·187	2·79
ω	...	1·655	1·662	1·612
ϵ	...	1·646	—	—

. Daphnite, Tolgus mine, Cornwall; analysis by C. O. Harvey (Hallimond, 1939, p. 443).
I. Thuringite, Schmiedefeld, Thuringia; analysis by H. Jung (1930, p. 186).
II. Diabantite, Farmington Hills, Connecticut; analysis by G. W. Hawes (1875, p. 455).

d atomic contents for chlorites related in composition to chamosite. Chamosite d magnesian chamosite have approximately the same content of silicon; phnite and thuringite have less, and diabantite markedly more. Diabantite o contains more magnesium than does magnesian chamosite, so that this pair minerals can be distinguished from each other by chemical analysis more isfactorily than iron-rich chamosite from daphnite and thuringite.

Whilst discussing the chemistry of chamosite it should be mentioned that the pirical formula $2SiO_2.R_2O_3.3RO.aq.$ employed by Hallimond (1939, p. 446) nly a rough approximation to those proportions to be expected on the basis Pauling's structural formula for the chlorites. The crystal-structure is based on mica-like layers bonded, not by alkali atoms, but by sheets of brucite. e general formula for such a structure is $[Si_{16-n}Al_n][R'''_nR''_{24-n}]O_{40}(OH)_{32}$. lues of total RO and R_2O_3 ($SiO_2 = 200$) and Si/Al_{IV}[1] for the tetrahedral layer can

[1] Al_{IV} represents aluminium atoms with fourfold co-ordination (i.e. forming tetrahedral ups AlO_4) which link up with SiO_4 groups to form the tetrahedral layer (Si + Al = 16) of chlorite structure.

be calculated for various values of n and the smooth curves drawn as in text-fig. When chemical analyses of various chlorites are calculated to yield the val shown in table V, then these can also be plotted and fall very near to theoretical curves. For a theoretical value of $Si/Al_{IV} = 2$ the correspon values of R_2O_3 and RO are 100 and 350, yielding $2SiO_2.Al_2O_3.3\frac{1}{2}RO$, wh approaches the empirical formula fairly closely The actual values of Si

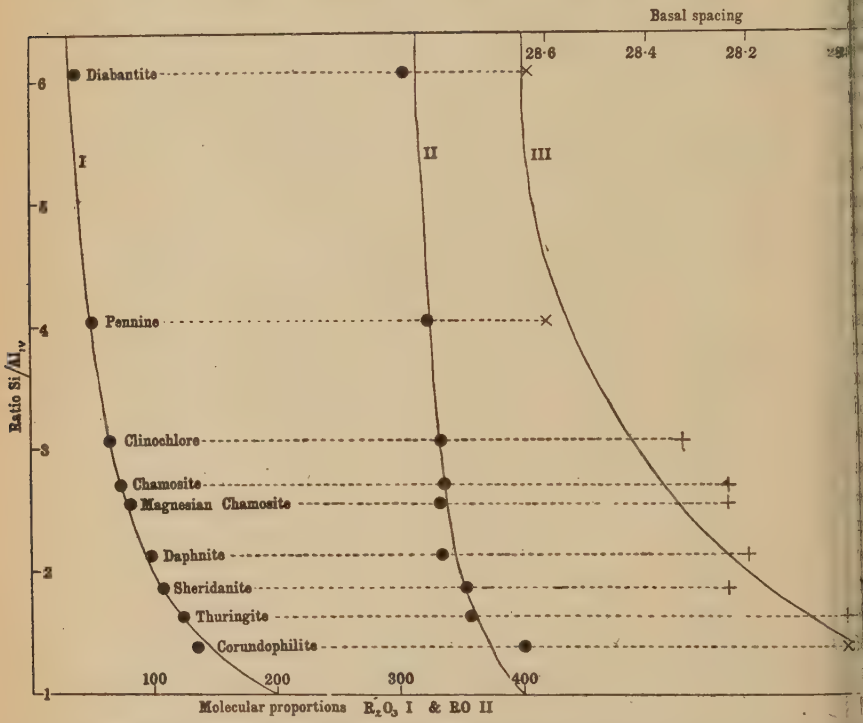

FIG. 1. Values of the molecular proportions of total R_2O_3 ($SiO_2 = 200$) (curve I), values total RO ($SiO_2 = 200$) (curve II), plotted with various values of the atomic ratio Si/A from the structural formula of the chlorites, $(Si,Al_{IV})_{16}(R''',R'')_{24}O_{40}(OH)_{32}$. Values of the quantities calculated direct from chemical analyses of various chlorites are shown as bla spots.

Curve III.—Values of the basal spacing $c^* = c \sin \beta$ in Å. plotted with Si/Al_{IV}. Crosses represent X-ray and chemical data obtained on the same specimen; × represent X-ray an chemical data obtained on different specimens from the same locality.

for chamosite and magnesian chamosite are, however, greater than 2 and th values of R_2O_3 are 335·5 and 328 respectively. Table V also gives the bas spacings $c^* = c \sin \beta$ for those chlorites whose chemical analyses have bee plotted on the first two curves of text-fig. 1. Curve III in the same figure show that as Si/Al_{IV} increases so the basal spacing increases. This is to be expected since the charge on the mica-like layers will become smaller with decrease in A and the layers will not be as tightly bonded together. Text-fig. 1 is a satisfactor method of showing graphically how far chemical analyses of chlorites approac the ideal structural formula quoted above.

TABLE V. Variation of the molecular proportions R_2O_3 and RO ($SiO_2 = 200$) and of the basal spacing with the ratio Si/Al_{IV} for various chlorites (text-fig. 1).

Species.	Si/Al_{IV}.	R_2O_3.	RO.	c^*.	Reference.
bantite	6·08	36·83	304·5	28·64 Å.	Hawes, 1875, p. 455.
nite	4·05	50·12	322·7	28·60	Tschermak, 1891, p. 45.
ochlore	3·07	64·89	333·3	28·33	Smith, 1924, p. 242.
mosite	2·71	73·89	335·5	28·24	Table III, p. 106.
nesian chamosite	2·56	81·30	332·0	28·24	Table III, p. 106.
hnite	2·14	97·81	334·5	28·20	Hallimond, 1939, p. 443.
idanite	1·87	106·9	353·0	28·24	Shannon, 1922, p. 241.
ringite	1·64	122·9	356·8	28·00	Pulfrey, 1933, p. 421.
ndophilite ...	1·39	135·3	398·5	28·00	Shannon, 1920, p. 375.

Spacing data by F. A. Bannister excepting for sheridanite (McMurchy, 1934, p. 423).

)uring the selection of chamosite ooliths from Wickwar for chemical analysis X-ray work, dark-green casts of fossils not exceeding ½ mm. across were asionally encountered. In appearance the microfossil casts resemble so closely ooliths of magnesian chamosite that no difference in powder pattern was ected. The pattern of two different microfossil casts gave, in addition to the gnesian chamosite pattern, a relatively strong line at 2·51 Å (pl. VIII, fig. 4). irst sight this might be thought to indicate admixture with iron-rich chamosite, e, as can be seen from table II, both chamosite from Frodingham and Schmiede- show a fairly strong line with nearly the same spacing. The specific gravity) and refractive index 1·61 are, however, both lower than the values for gnesian chamosite 3·034 and 1·620. The most reasonable assumption to fit se facts is that the microfossil casts are mixtures in fairly constant proportions n one to another of magnesian chamosite and serpentine. Too little material vailable for a determination of the magnesia and silica contents of the mixture, if it is assumed that the serpentine has specific gravity 2·65 and refractive ex 1·56, then the microfossil casts should contain 20 to 30 % serpentine. The tive intensities of the powder lines due to magnesian chamosite and to ser- tine alone are of the right order to confirm this approximate estimate of the portions of the two constituents in the microfossil casts. It should be noted the admixture of 25 % serpentine with magnesian chamosite would raise percentages of silica and magnesia to 30 and 18·5 % respectively. It has not n overlooked that possible admixture of normal iron-rich chamosite with cient serpentine would yield a chemical analysis with the correct content of gnesia for magnesian chamosite and only a slightly higher figure for silica. For ance, addition of 20 % serpentine to an iron-rich chamosite with a composition that of the Frodingham mineral would yield a mixture close in composition to gnesian chamosite. The powder pattern of this mixture would, however, show ked differences from that of the magnesian chamosite ooliths from Wickwar.

ur thanks are due to Mr. S. W. K. Morgan of the National Smelting Company, nmouth, who rendered welcome assistance by providing the spectroscopic ysis. The costs of the chemical analyses made by Geochemical Laboratories, of the collotype reproduction of the photographs for plates VIII and IX, e been met from the Colston Research Fund of the University of Bristol. he specimens here described and figured have been kindly presented to the eral Department, British Museum (Natural History), by Professor Whittard.

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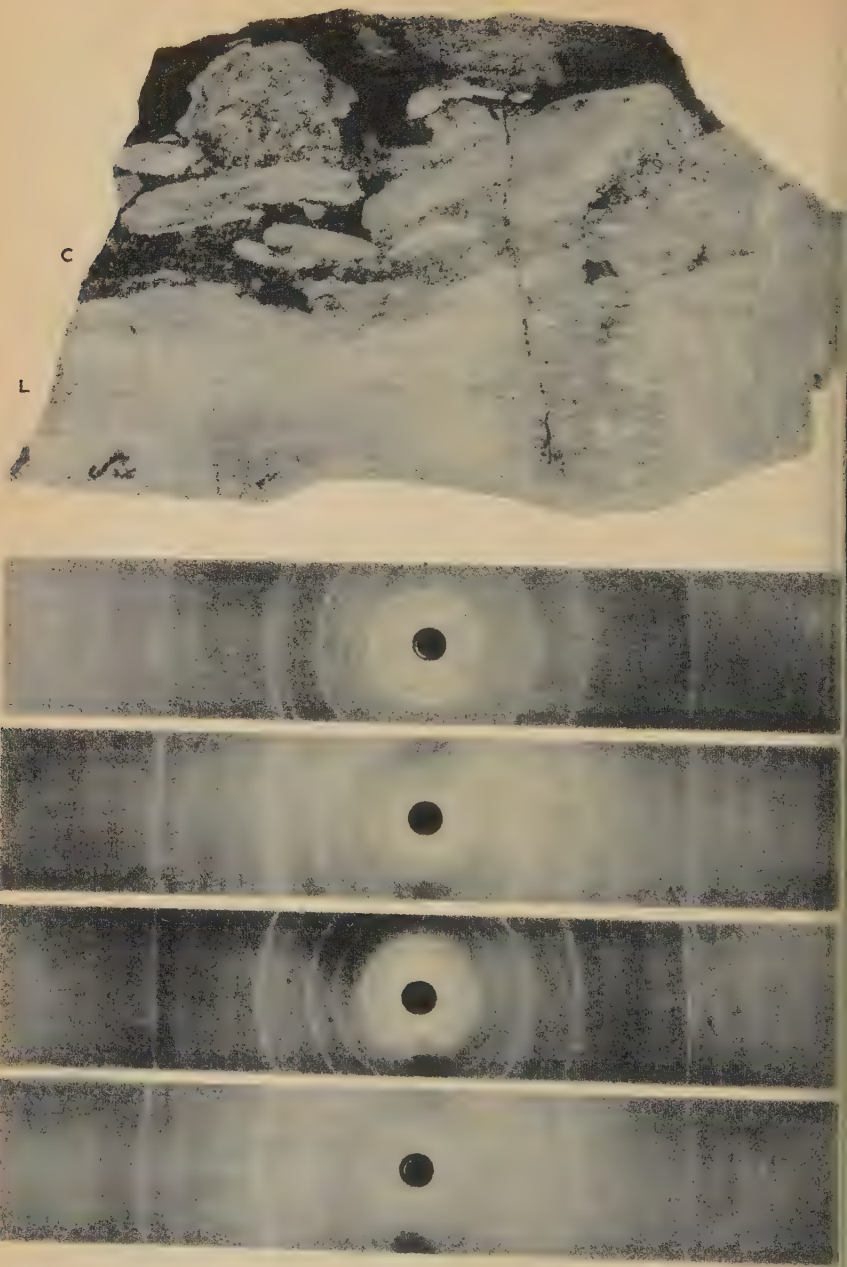
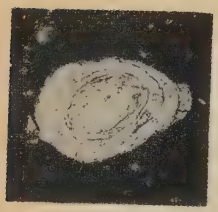


F. A. BANNISTER AND W. F. WHITTARD: MAGNESIAN CHAMOSITE.



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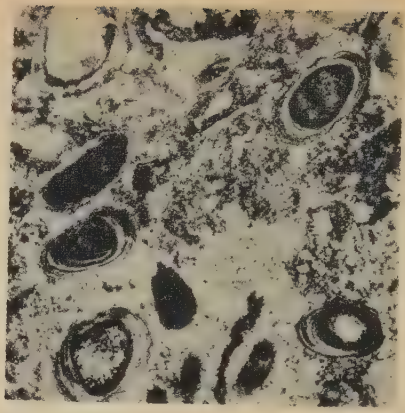

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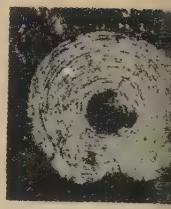

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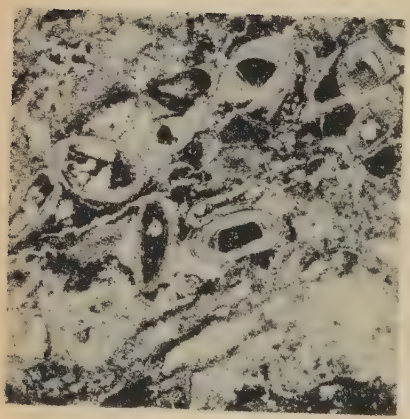

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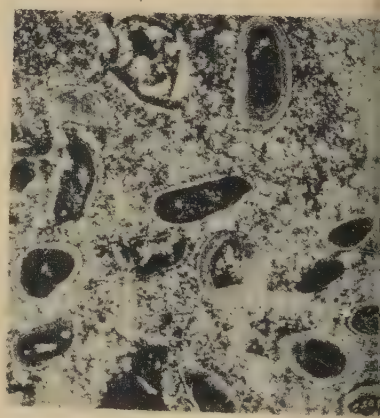

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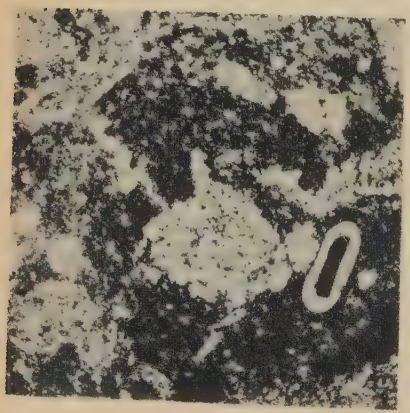

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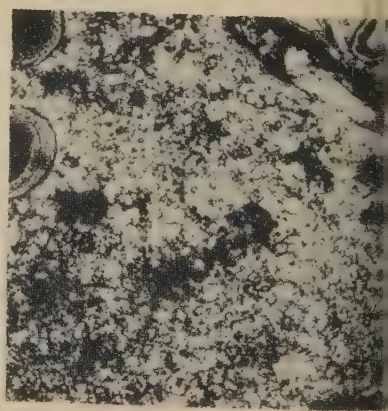

5

F. A. BANNISTER AND W. F. WHITTARD: MAGNESIAN CHAMOSITE AND 'PEARLS'.

Explanation of Plates VIII and IX.

ATE VIII, Fig. 1. Intraformational breccia, Wenlock Limestone, lower shaft, Little Avon river, Wickwar, Gloucestershire. Note the dolomitized, heavily crinoidal limestone (L) succeeded above by calcareous, chamositic siltstone (C); the latter contains irregularly-shaped pieces of non-crinoidal, calcareous mudstone, a section of the compound coral *Halysites*, and numerous detrital crinoid ossicles. At the lower right-hand corner the polished surface has obliquely cut across a joint now infilled with Triassic material (T). The specimen was photographed under water. B.M. 1945,46. $\times\frac{1}{2}$.

X-ray powder patterns taken in a cylindrical camera, diameter 6 cm. with unfiltered Fe radiation:

IG. 2. Chamosite, Frodingham, Lincolnshire.

IG. 3. Magnesian chamosite, Wickwar, Gloucestershire. B.M. 1945,46.

IG. 4. Magnesian chamosite and serpentine microfossil, Wickwar, Gloucestershire.

IG. 5. Diabantite, Connecticut valley, U.S.A. B.M. 53917.

ATE IX. Photomicrographs of magnesian chamosite and 'pearls' from the Wenlock Limestone, lower shaft, Wickwar, Gloucestershire.

IG. 1. Fresh chamositic ooliths, some with a nucleus o calcite, contained in a calcareous, chamositic siltstone matrix. B.M. 1945,47. $\times 21$.

IG. 2. Fresh ooliths of chamosite scattered in a calcareous matrix rich in dolomite, ankerite, and limonite. B.M. 1945,48. $\times 21$.

IG. 3. Weathered, calcareous, chamositic siltstone in which much of the chamosite in the matrix has been converted into limonite. The chamosite ooliths are yellowish-green in colour and show a pronounced banding due to a finely divided mineral believed to be rutile. B.M. 1945,49. $\times 21$.

IG. 4. Chamositic siltstone (dark patches) intermingled with calcareous mudstone which has been dolomitized. B.M. 1945,50. $\times 21$.

IG. 5. Calcareous mudstone matrix containing numerous rhombohedra of dolomite and ankerite; note the dark centres to the crystals. B.M. 1945,51. $\times 35$.

IG. 6. Detrital 'pearl' with a nucleus of chloritic matter which may be chamosite. B.M. 1945,52. $\times 35$.

IG. 7. Irregularly-shaped detrital 'pearl'. B.M. 1945,53. $\times 56$.

Photographs for pl. VIII, fig. 1, and pl. IX, figs. 1–7, by E. W. Seavill.

The shape of reflections on X-ray, single-crystal photograph

(With Plates X and XI.)

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Davy Faraday Laboratory, Royal Institution, London.

[Read March 22, 1945.]

Introduction.

In the early days of X-ray crystallography the study of the atomic a molecular structure of crystals was of primary importance. It was m necessary to know the arrangement of the atoms in, say, rocksalt, qu r diamond, or graphite, than to know the exact distances apart of the at or the small deviations from the mean atomic structure which may result f heat movements, eccentricity of growth, mechanical distortion, and other fact

Now, however, the range of problems is widening, and X-ray methods a being used as a research tool by many workers whose main interest is in o branches of science. It is necessary, therefore, to point out that the famil Bragg law, $n\lambda = 2d \sin \theta$, which relates order of spectrum n, wave-length crystal spacing d, and diffraction angle θ in an ideal crystal, though still of cou applicable, must be applied with some caution to crystals which are not ideal either structure or texture, and which may be of irregular or eccentric sha A case in point may be cited from recent scientific literature. R. S. Krishna found that the 111 reflection of an almost parallel beam of Cu $K\alpha$ radiation fr the oscillating octahedral plate surface of a particular diamond was record on a photographic film some 40 cm. away from the specimen, as a wavy li Applying the Bragg law directly, he interpreted this as meaning that there wa periodic variation in θ from top to bottom of the plate and that therefore d, t lattice spacing, must similarly vary, by as much as 1 in 2000, from region region in that diamond. The actual cause of the waviness of the reflection w much more probably a corrugation (and therefore an excentring of parts) of t crystal face. It will be shown later in this paper that apparent variations in do not by any means necessarily signify a variation in spacing, and ways finding out just what such variations do imply will be outlined.

In order to make the fullest use of the information given by a photograph, n only the position and intensity, but also the shape of the individual reflecti must be studied, and the distribution of intensity within each reflection. The have been many papers[2] on this subject in connexion with precision measuremen of lattice spacing using the powder method, and it has been shown that for proper interpretation of results, certain experimental conditions must be fulfille The use of a powder is not always either convenient or expedient, however, ev

[1] R. S. Krishnan, Proc. Indian Acad. Sci., Sect. A, 1944, vol. 19, p. 298. [M.A. 9–108.]

[2] A. J. Bradley and A. H. Jay, Proc. Physical Soc., 1932, vol. 44, p. 563 [M.A. 5–305 1933, vol. 45, p. 507. E. R. Jette and F. Foote, Journ. Chem. Physics, 1935, vol. 3, p. 60 G. W. Brindley and F. W. Spiers, Proc. Physical Soc., 1938, vol. 50, p. 17. A. J. C. Wils and H. Lipson, ibid., 1941, vol. 53, p. 245. A. Taylor and H. Sinclair, ibid., 1945, vol. 5 pp. 108, 126.

precision work; the crystal may be one which does not readily powder, or ch does not readily form a uniform powder; it may be a single specimen too ious to destroy; it may be unstable, or soft and easily distorted. Moreover, intensity of a line on a powder photograph is, generally speaking, small pared with that of the same reflection observed by means of single-crystal llation, and time of exposure may be an important factor, especially if the tal has to be maintained at a particular temperature or pressure, if it is roscopic or volatile, and so on. Resolution of reflections is also sometimes ossible in powder photographs. Now precision work *can* be attempted using le crystals if the shape of, and distribution of intensity in, the observed ctions can be interpreted in relation to the shape and other properties of the tal, to the divergence of, and distribution of intensity in, the incident X-ray n, and to the actual apparatus and photographic method used. A study of shapes of reflections is also useful in other respects. It may give information ut those very features of the natural crystal which would be lost by powdering r even by cleaving, fracturing, or working it in such a way as to obtain a imen of controlled shape. Or it may help to elucidate the actual effect of vage, grinding, temperature or pressure change, electrical or heat treatment, ng, &c., on surface or internal structure.

any investigation of this kind is to be carried out, however, it is essential the research worker should be able to distinguish between:

) effects due to experimental methods employed;

) effects due to crystal shape or size;

) effects due to divergence of, and distribution of intensity in, the incident n;

) effects due to absorption, extinction, and to distortion or imperfection ch involves only a difference between the surface layers and the main body ne crystal;

) effects due to distortion (either mechanical or incurred during growth) ch has produced a comparatively large disorientation of the crystallites which e up the main body of the crystal;

) effects which involve an actual change of structure without apparent change nape (e.g. some kinds of temperature transformation);

) effects which are due to an inherent lack of regularity in the atomic or ecular arrangement, whether the departure from regularity is of a static or namic kind.

ow it is not possible, in the course of a short paper, to deal exhaustively with hese effects, but it is hoped that, by indicating the main principles involved, e guidance will be given for the avoidance of major pitfalls.

Experimental methods.

ne various methods used in single-crystal work employ either a stationary tal, or a moving crystal and a stationary film, or a moving crystal and a ing film. Each of these methods will influence the shapes of the reflections different way. For the sake of completeness, the methods themselves will riefly outlined.

he Laue method.—In this method the crystal is held stationary in a particular ion, and θ, the angle between the incident beam (supposed strictly parallel)

and the normal to any particular set of crystal planes, is therefore invariabl *the planes are strictly parallel throughout the crystal.* The incident beam con a range of wave-lengths varying from a minimum, which depends on voltage applied to the X-ray tube, to an effective maximum, which dep upon the crystal itself (since $\sin\theta = \lambda/2d$ must be less than unity, and there $\lambda_{\text{effective maximum}}$ must be less than $2d_{\max}$). Each set of planes, of spacin orientation θ_L, will selectively reflect, out of the polychromatic incident b a wave-length λ such that $n\lambda = 2d \sin\theta_L$. The positions of the spots on photographic plate or film (e.g. pl. X, fig. 1) depend only on the crystal symme and setting, and the pattern changes markedly even for a small change in t setting. On the other hand, it follows that all cubic crystals, say, what their lattice constant may be, will give Laue pictures which, as far as the positi of the spots are concerned (but not the intensities), are identical for sim settings. Since, however, it is $n\lambda$ and not λ alone that is fixed by d and θ, *a s spot on a Laue photograph may sometimes be given by two or even three diff wave-lengths reflected in different orders.*

If the X-ray beam is not parallel and the crystal is not small, or if the pla in the crystal deviate from strict parallelism for any reason whatever, the Laue photograph will reveal the fact by a change of shape of the spots from t shape that would normally be expected according to a simple geometri construction.

If, however, the crystal planes (*hkl*) are irregularly spaced, but remain stric parallel to each other, the Laue spot corresponding to those planes will sh nothing unusual; the reflections from other sets of planes in such a crystal ma however, show abnormalities.

It will be realized that, in using the total X-ray output of any target, t distribution of intensity among the wave-lengths in the incident beam will far from uniform, especially if the applied voltage is high enough to excite t *K* or *L* radiation characteristic of the target; but this does not matter, becau the Laue method is not used for the determination of intensities of reflectio nor for the measurement of spacing, but mainly for the detection of cryst symmetry, twinning, or distortion, or for the determination of crystal orientatio

The rotation method.—In the rotation or oscillation method the crystal setti is continuously varied about a particular direction, usually a simple zone-ax but, ideally at least, the incident beam is parallel and contains only one wav length. (In practice, of course, even a single characteristic line such as t Cu $K\alpha_1$ has a finite width.) Since λ is invariable, the angle of selective reflecti θ_B must depend upon the spacing d. The position of a reflection on the phot graphic plate or film will depend also on the orientation of the reflecting plan relative to the rotation axis, this fact giving rise to the characteristic layer-li arrangement (pl. X, figs. 2, 4, 6). The dependence of θ_B upon d will be especial marked if d is small ($2\theta_B \rightarrow 180°$). *Any variation in crystal spacing, therefore, m be expected to produce big changes of position of the back reflections, or which 2 approaches 180°.*

Disturbances in the parallelism of the crystal planes will, however, only affe the positions or shapes of the spots on the film, if the inclinations of the plan to the rotation axis are thereby affected. This assumes, of course, that the fil is stationary.

loving plate or film methods.—In the Weissenberg method, the crystal rotates ut a zone-axis which is coincident in direction with the axis of a cylindrical , and the film itself moves parallel with this axis, its speed and extent of slation being synchronized with the rotation of the crystal. In the Schiebold– ter method the plate or film, which is parallel to the rotation axis of the crystal normal to the incident X-ray beam, rotates, synchronously with the crystal, ut its own normal. There are also other methods involving translations or tions of the film in other directions relative to the rotation axis of the crystal the direction of the incident X-ray beam.[1]

ow an X-ray reflection does not take place instantaneously; it necessarily upies an appreciable, though small, period of time, and during that time the will move. This may result either in a spreading or in a focusing of the ction, but it will certainly affect the shape in a way that bears a definite metrical relationship to the experimental set-up.

etailed consideration will not be given here to the interpretation of the results y to be obtained from moving-film photographs of crystals of irregular shape, cture, or texture, but it will be realized that in some respects these results be much more informative than those obtained from a simple rotation tograph. In a rotation photograph the position of a spot depends only on the ing and the direction of the plane normal relative to the rotation axis, so , for example, spiralling of the planes *about that axis* would not be detectable he simple rotation method. In a method involving translation or rotation he film, however, the *time* at which the reflection takes place is a crucial or. This time will vary for sets of planes which, though equally inclined to rotation axis and of equal spacing, are not parallel to each other, and the lt of spiral distortion about the rotation axis, for example, would be a change ength of the reflections in the direction of translation of the film. Any *dental* crystal movement will of course also affect spot shapes.

ocusing methods. Intensification.—Various methods have been devised for sing the reflections from a crystal. These include the use of bent crystal ochromators, and cameras in which the specimen is placed on the circum- nce instead of at the centre of the cylindrical film. Here again, it is the experi- tal arrangements that principally decide the shape of the X-ray reflection. larly, photographic intensification causes a loss of definition which should voided in any study of shape.

Effect of crystal shape upon the shape of X-ray reflections in the Laue and rotation methods.

often happens that crystals grow in the shape of needles or plates and must xamined in that form, since they cannot be cut without distortion. This ns that the spots on the film will be of varying shapes. If the incident beam rallel and crystal absorption is negligible, the shape of the spot, whether in Laue or the rotation method, will be given by the projection of the crystal e on to the film, along the direction of the particular reflected beam, over period during which the reflection is taking place (fig. 1). Pl. XI, fig. 4, s the shape of the spots obtained by Laue reflection from the surface of a

[1] International tables for the determination of crystal structures. Berlin, 1935, vol. 2, 6. [M.A. 6–145.]

large (distorted) diamond plate. Even allowing for the distortion, the irregu shape of the surface is quite obvious.

For a disk-shaped crystal, some spots will be disk-shaped, others needle-sha (pl. XI, fig. 2). When the Laue method is used, the shape of the spot is deci (for a parallel beam and non-absorbent crystal only) by the orientation of t crystal relative to the film and the incident beam, because the crystal is reflecti

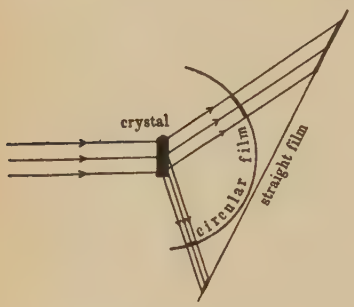


FIG. 1.
Effect of crystal shape on shape of spots.

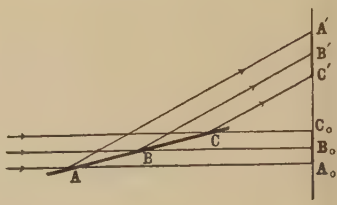


FIG. 2.
Differences in point of origin for angle θ.

all the time. When the rotation method is used, the shape of the spot will dependent upon the crystal orientation *at the time of reflection* and upon t spacing, which controls the reflecting angle. Spots that are disk-shaped in t one method may quite well be needle-shaped in the other.

One simple point that must never be lost sight of in making observations photographs of a crystal of finite size, using a beam of finite section, is that t origin from which θ is to be measured varies from point to point in the cryst

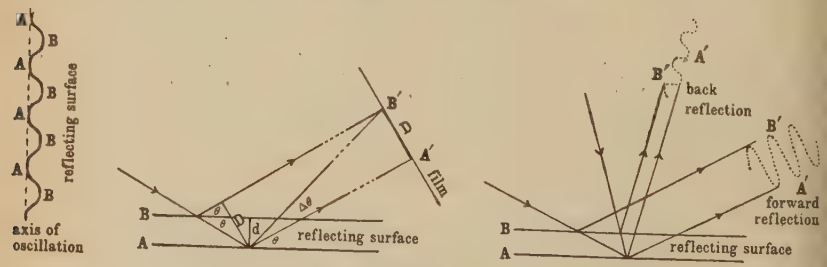


FIG. 3. X-ray reflections from a corrugated surface.

fig. 2). The point A will reflect to A', the point B to B', and the point C to C The angle of deviation of the ray AA' is $A'AA_0$, not $A'BB_0$, although B may l the true axis of rotation and B_0 the true centre of the photograph. This obvious in the case illustrated, but it is not so obvious in the case of, say, surface which is uneven or spherical, when the true centre of rotation is difficu to locate and is not, perhaps, at the centre of the reflecting region. In the ca of the diamond surface used by R. S. Krishnan, for example, a vertical corr gation (fig. 3) involving an excentring of parts B of the surface by 0·004 cm

ld cause an apparent variation in θ_{III} of the order found ($\sim 0{\cdot}7'$), since if the amount of excentring and $\Delta\theta$ the apparent change of θ,

$$\frac{d}{\sin\theta} = \frac{D}{\sin 2\theta} = \frac{L.\Delta\theta}{\sin 2\theta} \quad (\theta = 22°, L = 40 \text{ cm.}).$$

t will be seen from the formula, or from the diagram, however, that for the n-order reflections ($\theta \to 90°$) the variation in θ caused by the same amount of ugation would be *less*, since $\sin 2\theta/\sin\theta$ is a maximum for $\theta \to 0$ and a imum for $\theta \to 90°$. This is in direct contrast to the *greater* variation in θ for n-order reflections that would result from a variation in spacing.

he *broadening* of the reflections that is the consequence of extreme smallness he crystallites (10^{-6} cm. or less linear dimensions) is more often met with in der or fibre diagrams than in single-crystal work, although it may occur, the shape of the crystallites (spherical, acicular, or disk-like) will influence broadening, which may, for crystallites of anisotropic shape, be very different different reflections.[1] The broadening due to this cause is always much greater back reflections, if the crystallites are spherical.

Divergency of the incident beam, and shape of focal spot.

f the incident beam is not quite parallel (and it never is) the actual dimensions he spot will depend on the crystal → film distance. On Laue photographs en at any distance a focusing of some spots (usually those for which θ is small) a spreading of others will result. This is well shown on pl. X, fig. 1, which Laue photograph of a large undistorted crystal of urea oxalate placed with ongest dimension vertical and parallel to the film.

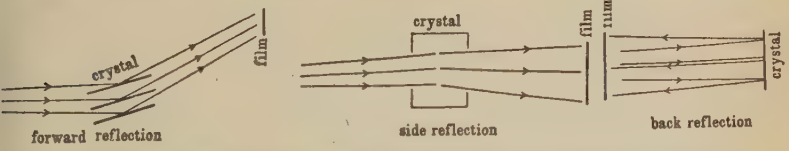


FIG. 4. Laue method, showing broadening of side and back reflections.

FIG. 5. Rotation method, showing focusing of back reflections.

simple sketch shows that the tendency of a divergent beam is to broaden back reflections in a Laue photograph (fig. 4), while in a rotation photograph back reflections are focused and the forward reflections are broadened or orted (fig. 5).

f the crystal is large enough to cover the whole of the divergent beam, then

P. P. Ewald, Proc. Physical Soc., 1940, vol. 52, p. 167 [M.A. 8–133]. M. von Laue, . Physik, **1936**, ser. 5, vol. 26, p. 55.

the spots on Laue or on rotation photographs may not have very sharp edg
because the X-rays at the edge of the beam will be less concentrated than th
in the properly collimated middle (pl. XI, fig. 4).

It is frequently found that, in Laue photographs taken with a slightly diverg
beam, a sharp intense spot of well-defined shape (sometimes a double
superimposed, not necessarily centrally, upon a bigger, fainter, and perhaps m
diffuse spot (pl. X, fig. 3; pl. XI, fig. 1). This happens when the planes of
crystal are so orientated as to p
out for reflection a characteris
wave-length. They can only do th
however, if the angle θ is just rig
and the *whole* of the divergent bea
therefore, will not be used, but on
a parallel section of it, which may
quite narrow relative to the wid
of the whole beam (fig. 6): a sm
intense spot will result. At the sam
orientation, however, the crystal m
be reflecting the whole of the div
gent beam from the same plane, b

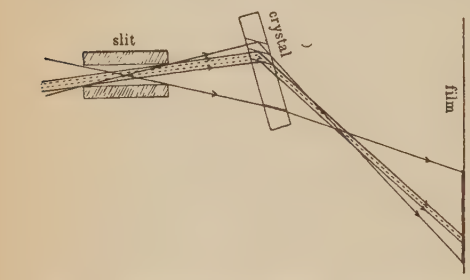


FIG. 6. Characteristic reflection superimposed on reflection of general radiation, in Laue photograph.

perhaps in another order (such that $n_1/n_2 = \lambda_2/\lambda_1$), over the range $\theta+\Delta\theta$ to $\theta-\Delta$
This coincident spot will probably be much fainter. A small movement of t
crystal either way will usually cause the partial or complete disappearance
the sharp 'characteristic spot', although the spot that remains will still be giv
by wave-lengths reflected in different orders (pl. XI, fig. 1).

If the slit system is not fully collimating, the shape of the focal spot on th
target of the X-ray tube is a very important factor in deciding the shape of th
reflections. Pl. XI, fig. 3, shows the comparative photographs given by fo
different X-ray tubes of a small benzil prism (height about $1\frac{1}{2}$ times width
rotating about its longest dimension. In (*a*) the tube had a horizontal line focu
which was at right angles to the height of the prism, and the effect of cryst
shape is, to a large degree, cancelled. In (*b*) the tube had a vertical line focu
parallel to the height of the prism, and the effect of anisotropy of crystal shap
is accentuated. In (*c*) the focus was circular but ill-defined, whereas in (*d*) it wa
circular and fairly sharp. The same slit system was used in all four experiment
only the X-ray tube was changed. The same effect can be demonstrated usin
a tube with a line focus, and turning the crystal itself through 90° about th
direction of the X-ray beam. Pl. X, figs. 3 and 5, are Laue photographs of th
same needle of urea oxalate placed with its length vertical and horizont
respectively, and parallel to the film in each case. If the focus were circular
the slit system correctly collimating, the photographs should be identical if o
is turned through 90°.

The three factors considered so far, that is, the particular X-ray method use
the shape of the crystal, and the shape of the incident beam, are not usuall
studied for their own intrinsic interest. But it may be necessary to take them ver
seriously into account, before the shapes of the reflections can be used to giv
information about the remaining factors, which are more important from
crystallographic point of view.

Absorption, extinction, and surface effects.

he effect of absorption must, of course, be considered as much in the case of le crystals as for a powder, or even rather more, since added to the ordinary orption there will be the 'extinction' (primary and secondary) which depends the state of perfection of the crystal.[1] A perfect crystal will reflect only a tion, say one-thirtieth, of the intensity reflected by a crystal mosaic, and this inction', although difficult to estimate or to measure,[2] is not difficult to erve. It is frequently found that spots Laue or on rotation photographs are bled. Such doubling may be the result rdinary absorption and path differences 7). In that case it is usually found for rather than for short wave-lengths. te frequently it is observed for the aracteristic spots' mentioned in the section, although the high-order, short wave-length spots on which they superimposed do not show it (pl. XI, fig. 1).

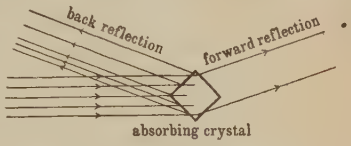


FIG. 7. Doubling of spots due to absorption.

he doubling, however, is quite often due to the fact that the surface of a tal is more mosaic, less perfect, and therefore a much better reflector than inside.

is reported that if a quartz crystal is subjected to standing supersonic waves, disturbance of the atoms at the antinodes causes the crystal to become more aic and to reflect better at these points, and the double spots previously rved on Laue photographs become multiple spots, the number of components ring with the mode of vibration.[3]

the crystal surface is not only a mosaic but is subject also to strain, other ts will be observed that are considered in a later section.

Crystal distortion, with special reference to 'spiral structures'.

has already been mentioned that if the individual crystallites of which the tal is ordinarily composed are sufficiently small, a broadening of the reflections occur. A similar broadening might also occur if the crystal were a mixture rger grains of different lattice parameters or if there were actual structural ortions (uneven expansions and contractions, warping or curving of planes) ie individual grains.[4]

, however, there is a *regular* distortion of the crystal, such as the 'spiralling' ribed by Bernauer as characteristic of many single crystals of organic com- nds, and observed by him by means of the polarizing microscope,[5] then some

P. P. Ewald and M. Renninger, The solid state of matter. Internat. Conf. Physics, lon, 1934, vol. 2, p. 57.

R. W. James, Zeits. Krist., 1934, vol. 89, p. 295. Summary of earlier work, with references.

S. Nishikawa, Y. Sakisaka, and I. Sumoto, Physical Rev., 1933, vol. 43, p. 363. M. Y. and S. Harris, ibid., 1934, vol. 46, p. 445. F. Klauer, Physikal. Zeits., 1935, vol. 36, 8.

E. Orowan and K. J. Pascoe, Nature, London, 1941, vol. 148, p. 467. E. Orowan, ibid., vol. 149, p. 643. A. R. Stokes and A. J. C. Wilson, Proc. Physical Soc., 1944, vol. 56, 4.

V. Bernauer, Zeits. Krist., 1926, vol. 64, p. 505; Fortschr. Min. Krist. Petr., 1927, vol. 11, 3. L. J. Spencer, Curvature in crystals. Min. Mag., 1921, vol. 19, p. 263.

most peculiar and unmistakable effects will be found on Laue photograp even when rotation photographs show little or nothing out of the ordinary. Si these effects have not been discussed previously, they will be described here some detail. They sometimes indicate a spiralling which has occurred dur growth, and sometimes a spiral distortion due to cleavage. Crystals of u oxalate $2CO(NH_2)_2.C_2H_2O_4$, provide a good example of the latter. They monoclinic, a 7·02, b 12·42, c 5·08 Å., β 97° 30′, space-group $P2_1/a$, two mole in the unit cell. The atoms are arranged in layers parallel to the ($\bar{2}01$) p which is in consequence an excellent cleavage plane. The crystals are platy habit, with the large natural face parallel to (010), and it is quite easy to ob cleavage needles, the length of which is parallel to the zone-axis [102]. If needles are sufficiently thin, the cleavage produces a slight spiralling about t [102] axis. The result on a Laue photograph taken with the X-rays parall the symmetry plane and perpendicular to the spiral axis is shown in pl. X, fig Here the spiral axis and the plane of symmetry are both vertical. It will be that although the spots on the left-hand side of the photograph are in *positi* which are the mirror-image of those on the right-hand side, there is a mark asymmetry of *shape*. All the spots, in fact, are either focused or are tilted throu various angles in an anti-clockwise direction from their normal mirror-ima orientations. This rotation of the spots is observed no matter which plan the [102] zone is parallel to the X-ray beam (pl. X, figs. 3, 8), and its amount a direction vary in different crystals. By considering only the reflections fro planes in the [102] zone, it is possible to calculate the pitch of the screw. It w

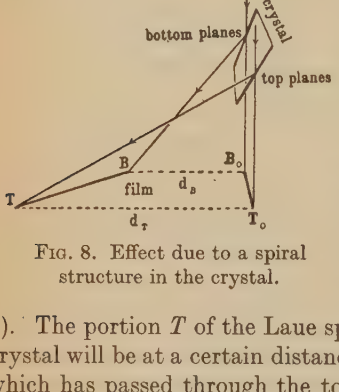


Fig. 8. Effect due to a spiral structure in the crystal.

be remembered that the position (distan and direction) of any *part* of a Laue spo relative to its corresponding origin on t film, gives the direction-cosines of the norm to the reflecting planes in the correspondi part of the crystal, due allowance being ma for size and divergence of the incident bea Since the planes are spiralling slightly abo [102], the plane normals at the top a bottom (say) of the needle whose vertic length is parallel to [102] will be different orientated relative to the incident beam (fi 8). The portion T of the Laue spot which is due to the planes at the top of t crystal will be at a certain distance d_T from the origin T_o (trace of central bea which has passed through the top of the crystal), and this will differ from t distance d_B corresponding to the same planes at the bottom of the crystal. If is the crystal → film distance, then the angle through which the plane norm has twisted from top to bottom will be $\frac{1}{2}(\tan^{-1}d_T/D - \tan^{-1}d_B/D)$. The ur oxalate cleavage needle giving pl. X, figs. 3, 5, 7, was found to be spiralling abo [102] in a left-handed screw direction by about 16 minutes per millimetre.

A comparison of Laue photographs taken with a particularly long needle wi the [102] spiral axis placed horizontally (a) parallel to the film and (b) paral to the X-rays and therefore perpendicular to the film, shows a remarkab difference in the two cases (pl. X, figs. 5, 7). In the case (a) the size of t collimator pin-holes limits the size of the reflecting portion of the crystal, a

spots, although showing the individual distortion that has been described
connexion with pl. X, fig. 3, do not give anything like the impression of over-all
tortion that is gained from (*b*), where the whole crystal is reflecting. One
uld hardly believe that it is the same crystal giving these two photographs,
l that all that has been done is to turn the crystal through 90° about a vertical
s. When the spiral axis is parallel to the incident X-ray beam, the effect is
superimpose a screw motion of the whole pattern on whatever symmetry
uld normally have been present. It must also be remembered that, quite
rt from any distortion effect, the pattern from the part *A* of the needle nearest
he source of incident X-rays will be appreciably larger than that from the
t *B* nearest to the film, owing to the variation in effective crystal → film
ance from *AO* to *BO* (fig. 9).

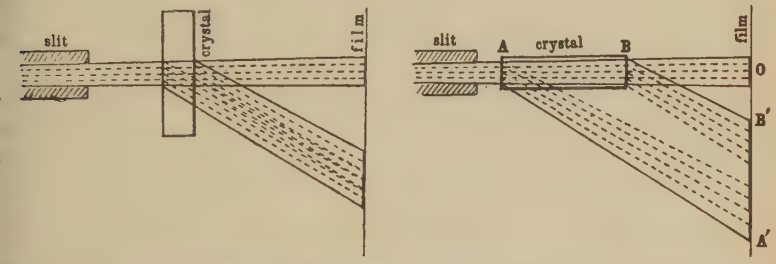


FIG. 9. Crystal with spiral structure: (*a*) parallel to the photographic film, (*b*) parallel to the X-ray beam.

Of course, it will be realized that any kind of angular distortion, such as
ving or kinking of the crystals (Orowan and Pascoe, loc. cit.), will be similarly
ealed by means of Laue photographs.

Rotation photographs can give the same information, but they give it in a
erent way. When a spirally distorted crystal, such as urea oxalate, is rotated
ut the spiral axis, the rotation photograph obtained on a stationary plate or
is a perfectly normal one, showing no apparent distortion at all (pl. X, fig. 2)
ept perhaps that due to the combination of a vertical needle and a slightly
ergent beam. If the film were moving parallel to the axis of rotation (as in the
issenberg method) some reflections would be lengthened and some shortened,
without any variation of the Bragg angle θ. When the needle axis is tilted
he vertical, the rotation photograph shows variously tilted spots (best resolved
en the rotation axis is not quite coincident with a zone-axis), where shapes
distorted in different ways by the superimposed spiralling (pl. X, fig. 4).
s distortion of the shapes of the rotation spots is most marked when the spiral
is perpendicular to the axis of rotation; and in this case (pl. X, fig. 6) some
ts may occasionally be found to show angular spreading over quite a con-
rable range.

Orowan and Pascoe (loc. cit.) have shown that it is possible, by means of
ition photographs, to distinguish between lattice curvature and fragmentation
disorientated crystallites. If the curvature is continuous, reflected rays from
side of the crystal will converge, and from the other side they will diverge,
ng very differently shaped spots in different quadrants of the photograph.
purely random disorientation of the crystallites through a small range of

angles will cause a spreading of rotation spots along 'powder' circles. Pl. X fig. 8, shows such a spreading found in the case of a very small crystal of bröggeri The extension of the spots is least for Bragg angles near to 45°. On Laue pho graphs a small random disorientation of this kind leads to 'asterism', a ra elongation of the reflections, which are drawn out into ellipses whose major a is perhaps several times longer than the minor. If the Bragg angle is θ radia the ratio of major to minor axis is approximately $1/\theta$.[1] This means that the sp nearest to the central spot are drawn out the most. Pl. XI, fig. 7, shows t asterism effect for the very small crystal of bröggerite, in which, however, th is also a slight tendency to spiral.

Pl. XI, fig. 6, is a Laue photograph of diamond which at first appears to sh asterism. In fact, however, it is seen that the spreading of the spots is gre for larger angles of θ, an effect which is clearly due to crystal shape (the diam was a plate placed nearly parallel to the incident rays) and to the divergency the X-rays used. In general, the distortion seen in rotation or oscillation ph graphs is not so easy to interpret, nor so informative as that observed by Laue method. The rotation and oscillation methods are particularly useful f the observation of small changes of lattice dimensions or structure which invol little or no change of crystal shape.

Effect of change of structure without change of crystal shape.

Some recent observations by Ubbelohde and Woodward[2] provide an excelle example of this effect. They have found that X-ray rotation photographs of suc crystals as Rochelle salt and potassium dihydrogen ortho-phosphate show splitting of some reflections when the temperature lies within the Curie region fo the particular crystal, although the same crystal gives single reflections a temperatures both above and below that range. The crystal, outwardly at leas is not broken up, and certainly recovers from any sub-crystalline breaking-u that may temporarily occur within the region. Now a splitting of Laue spot might be explained by absorption or by a variation of the texture of the crysta as has been pointed out earlier in this paper, and a splitting of rotation spot could be due to the same effect, the outer parts of the crystal being less absorbin or better reflecting than the middle. But in that case the forward reflection would show the splitting rather than the back reflections (fig. 7). In Ubbelohde' and Woodward's photographs the splitting is most marked in the back reflections showing that a real variation of spacing is involved; and it is only shown b *some* planes. Others remain unaltered or are split to a much less degree. It i found that the results are explained by assuming that the structure, orthogona above and below the Curie region, changes within that region to a sub-crystallin combination of two less symmetrical forms which are, however, only slightl different from the original in lattice angles and parameters. In Rochelle salt for example, a change of the angle between the b and c axes from 90° to 90° 2 or 89° 58′, without any change of length of the axes themselves, accounts quit rigorously for the observed splitting of the reflections.

Similarly, the changes of spacing corresponding to thermal expansion, isotop

[1] W. H. Bragg and W. L. Bragg, The crystalline state. London, 1933, vol. 1, p. 20 [M.A. 5–385.]

[2] A. R. Ubbelohde and I. Woodward, Nature, London, 1945, vol. 155, p. 170.

stitution, elastic strain, and so on, can be measured by means of rotation tographs, but not by the Laue method. Such changes are always observed means of back reflections ($2\theta \rightarrow 180°$) for which the percentage change of tion is greatest and the apparent variation in θ due to divergency of beam or erfection of the single crystal is usually least. These changes of spacing do involve a noticeable change of shape.

here are many cases of crystals which are composed of crystallites having crystallographic direction only in common. Examples of these, which include vn aluminium wire and fibre photographs, are given in Bragg's book 'The talline state'. Such crystals give photographs which are similar to rotation tographs, but usually with somewhat extended and diffuse spots. They not, of course, be regarded as single crystals, but the transition from such ntated crystal agglomerates to true single crystals is a gradual one, depending n the amount of disorientation of the remaining crystal directions.

Lack of regularity in single-crystal structure.

he atoms in all crystals are vibrating about their mean positions with a uency that is small compared with the frequency of X-rays. Any such ation can therefore be regarded, from the point of view of the X-rays, as a of instantaneous *displacements* of the atoms from their mean positions. In case of thermal vibrations, the displacements are dependent upon the elastic es in the lattice, and of course upon the temperature. There are many other ors, however, which may lead to the displacement, either permanent or isient, of the atoms from their mean positions. A system of permanent lacements, due for example to strain, is sometimes referred to as a 'frozen t motion'.[1] Any such displacement, whether static or dynamic, can be nally considered as due to a pattern of stationary waves in the crystal and give rise, therefore, to a non-Laue scattering of X-rays (pl. X, figs. 3, 7). rmal vibrations give very typical diffuse background effects which are most ly observable on Laue photographs taken with an incident X-ray beam which either been monochromatized or includes an intense characteristic component.[2] se effects are often seen as quite strong *diffuse* spots in the near neighbourhood *sharp* Laue spot. Pl. X, fig. 8, shows the diffuse spots corresponding to the action of Cu $K\alpha$ and Cu $K\beta$ radiation by waves modifying the structure of $(\bar{2}01)$ 'layer' plane in urea oxalate. It is very clear that the diffuse spots are lly distorted at all by the spiralling of the structure, although they are bably slightly enlarged. The contrast in their shape and that of the $(\bar{2}01)$ e spot lying between them is quite striking. The standing waves giving rise hese diffuse spots correspond to an oscillation of the individual atoms and refore, in a sense, to an apparent oscillation of the whole crystal;[3] the super- tion of a small spiralling in any direction will have little more effect upon shape of the diffuse spots than upon that of the spots of a rotation photograph n the axes of rotation and of spiralling coincide.

G. W. Brindley, Proc. Physical Soc., 1940, vol. 52, p. 117.
K. Lonsdale, Reports on Progress in Physics (Physical Soc.), 1943, vol. 9 (for 1942–3), 56.
K. Lonsdale and H. Smith, Proc. Roy. Soc. London, Ser. A, 1941, vol. 179, pp. 14–15.
. 8–209.]

Any strain or distortion involving a breakdown of crystal periodicity may give 'extra' spots on Laue photographs, but as a rule spots due to such distortion are sharp, not diffuse, and they are not temperature-sensitive. Bose[1] has described the most interesting case of a crystal, phloroglucine dihydrate, in which there is a breakdown of the periodicity along the *c*-axis *in the outer parts only of the crystal*, with the result that the 'extra' spots found are all hol The inside of the crystal does not give the non-Laue scattering. The partial breakdown of *c*-axis periodicity results also in the appearance of weak continuous lines connecting the spots in some zones found on the Laue photographs.

E. Aruja[2] has described photographs of chrysotile, a fibrous mineral of the asbestos group, which show a drawing-out of spots *along the layer-lines*; this indicates a perfect periodicity along the fibre length, but a partial breakdown of periodicity normal to that direction.

The presence of foreign atoms in any structure will cause local disturbance and a solid solution of one kind of atom in the lattice of another may give sufficient disorder to lead to diffuse spot effects very much like those characteristic of thermal vibrations. The occurrence of 'holes' in the structure, if sufficiently frequent, should have a similar effect. The segregation of the solute atoms, or some of them, as a separate phase may be characterized, in its initial stages, by the appearance of 'ghosts', streaks, and diffuse spots, which have received special attention in connexion with the effects of heat-treatment of alloys.[3]

Certain substances, such as cobalt, can crystallize in either of two closely related modifications, which may coexist over a certain range of temperature. Edwards and Lipson[4] have found that in the hexagonal form of cobalt, which is stable at room-temperatures, 'mistakes' occur at random intervals along the hexagonal axis because there are two different ways in which one close-packed layer of atoms can be fitted on to another and the structure occasionally goes the wrong way. This causes a diffuse broadening of some of the lines on powder photographs, but on single-crystal oscillation photographs there is a spreading out of some spots along definite lines.

All cases of structural irregularity in crystals are most easily investigated by the use of reciprocal lattice methods of interpretation (James, loc. cit.), but to consider these in any detail would bring us far beyond the range of this paper.

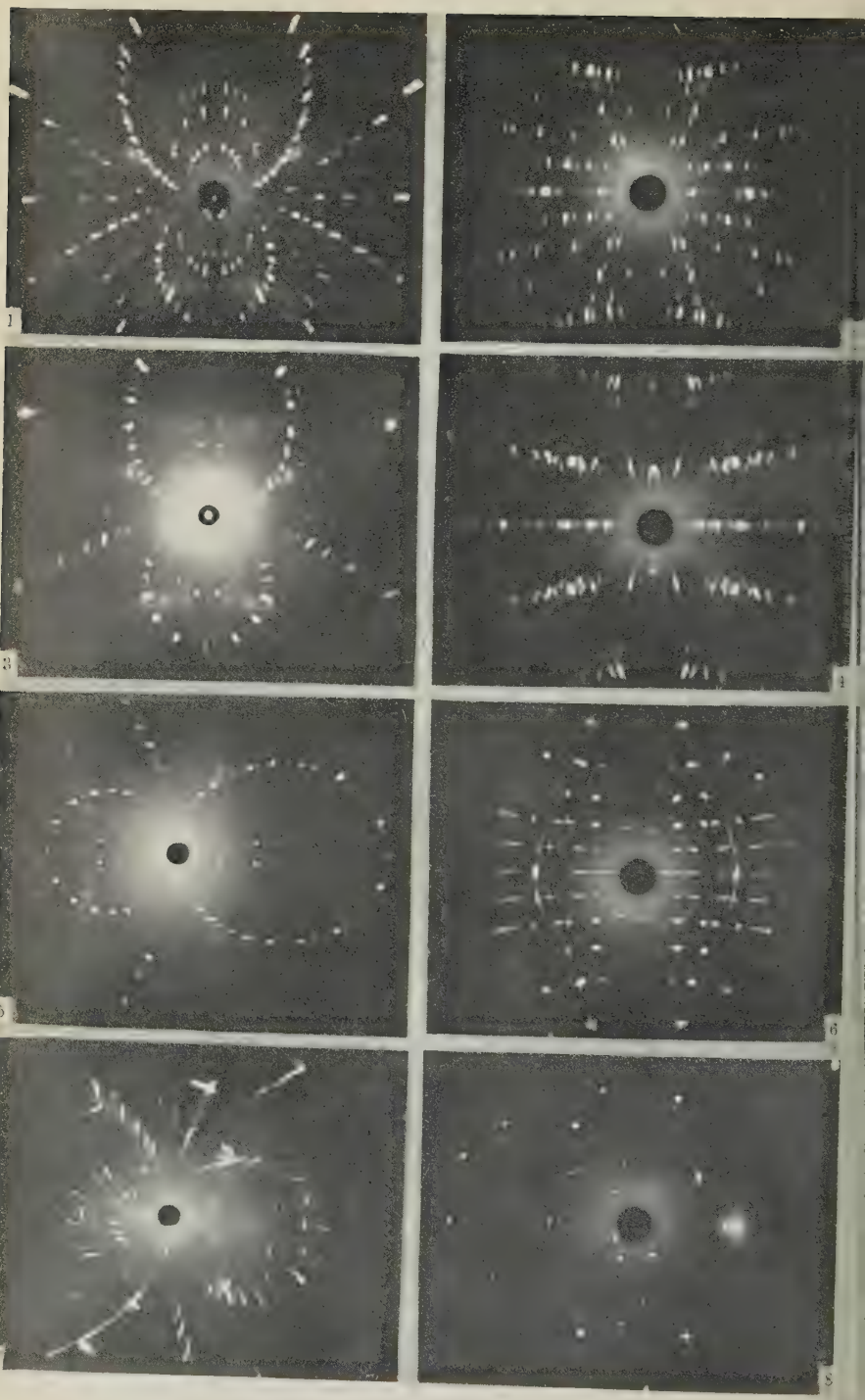
Summary.—The shapes of the spots observed on X-ray photographs of single crystals are influenced by the experimental method used, the properties of the incident beam, and the shape, absorption, structure, and texture of the crystal examined. If the first three factors can be allowed for, it is possible to obtain useful and interesting information concerning the sub-crystalline structure and the departures from regularity of the atomic or molecular arrangement. The limitations of the particular X-ray method used are illustrated by Laue and rotation photographs of a spirally distorted crystal of urea oxalate, and spiral and asterism effects in diamond and bröggerite photographs are also shown.

[1] C. R. Bose, Proc. Nat. Inst. Sci. India, 1944, vol. 10, p. 201.

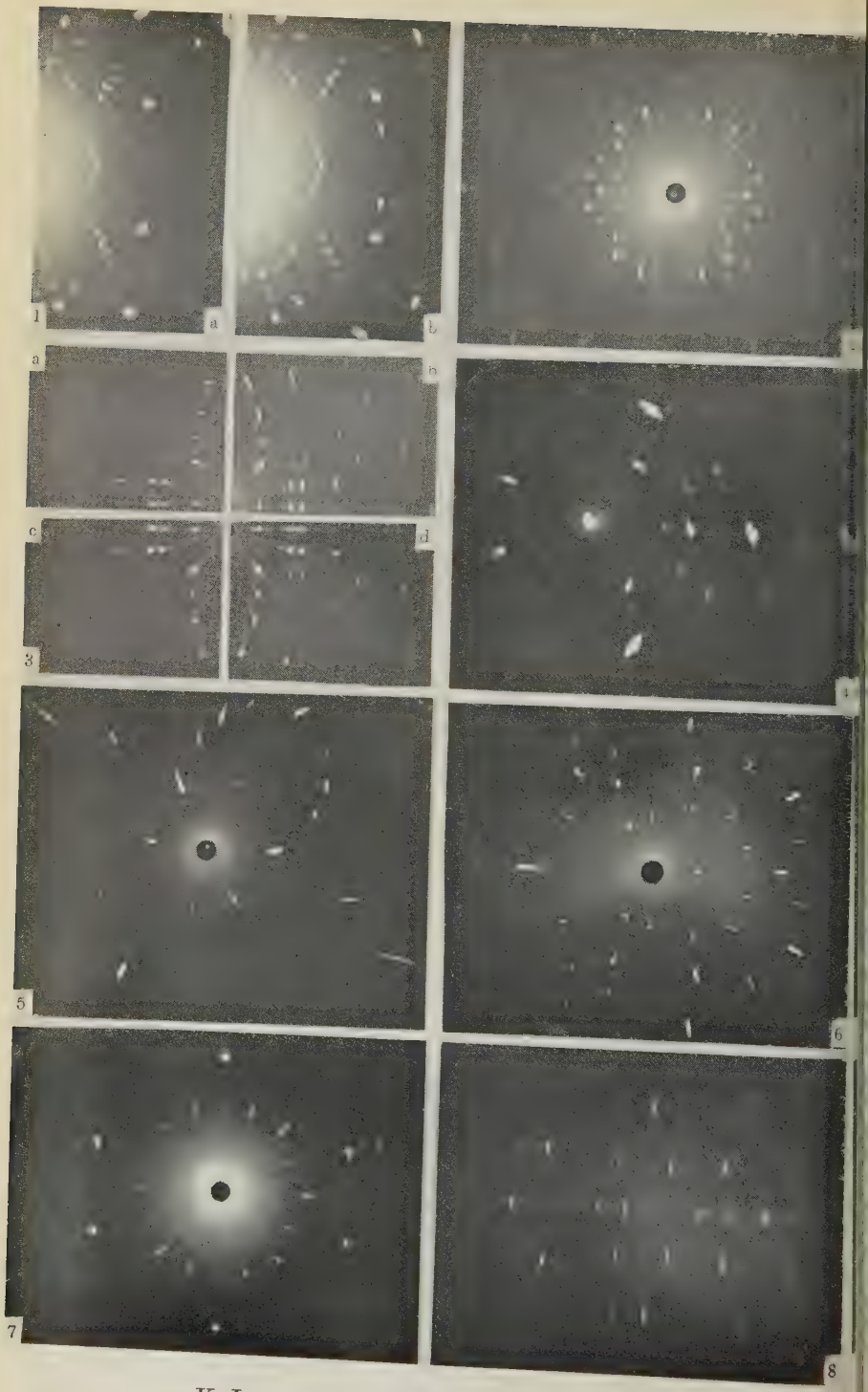
[2] X-ray analysis in industry. Nature, London, 1944, vol. 153, p. 534.

[3] A. Guinier, Compt. Rend. Acad. Sci. Paris, 1938, vol. 206, p. 1972; 1943, vol. 217, p. 2 G. D. Preston, Proc. Physical Soc., 1940, vol. 52, p. 77. V. Daniel and H. Lipson, Proc. Ro Soc. London, Ser. A, 1943, vol. 181, p. 368.

[4] O. S. Edwards and H. Lipson, Proc. Roy. Soc. London, 1942, vol. 180, p. 268. [M. 8–284, 362.]



K. Lonsdale: Shapes of X-ray spots



K. Lonsdale: Shapes of X-ray spots

Explanation of Plates X and XI.

Plate X consists entirely of photographs of urea oxalate.

g. 1. Laue photograph of undistorted plate, length [102] vertical, large face (010) parallel o incident X-ray beam, small face ($\bar{2}01$) parallel to photographic film. Shows effects due o beam divergence and crystal shape.

g. 2. Rotation photograph of needle, spirally distorted about [102] axis, which is parallel o the length of needle, and about which rotation takes place. Shows effects due to beam divergence and crystal shape only.

g. 3. Laue photograph of needle, spirally distorted about [102] axis, which is parallel to ength of needle. Placed as for fig. 1, showing effects due to beam divergence, crystal shape, piral distortion, atomic displacements due to strain and thermal vibration. Also shows Laue spots given *in different orders* by general and characteristic radiation.

g. 4. Rotation photograph about [001] vertical, length of needle tilted to vertical, showing effects due to beam divergence, crystal shape and excentring due to tilt, and spiral distortion.

g. 5. Laue photograph of same crystal as in fig. 3, turned through 90° *about incident beam direction*. Showing effects due to beam divergence, crystal shape, shape of X-ray tube focus, spiral distortion, atomic displacements due to strain and thermal vibration.

g. 6. Rotation photograph about [010] vertical, spiral axis [102] horizontal, showing pronounced distortion of spots due to spiral distortion of crystal, and spreading of ($\bar{2}01$) reflections in particular.

g. 7. Laue photograph of same crystal as in fig. 5, turned through 90° *about vertical direction*. Length of needle now parallel to incident X-ray beam. Shows effect of crystal shape and distortion, and also strong non-Laue reflections due to strain.

g. 8. Laue photograph of distorted needle, [102] vertical, placed so that ($\bar{2}01$) plane is reflecting at an angle *between* the Bragg angles corresponding to Cu $K\alpha$ and Cu $K\beta$. Showing effect due to crystal distortion and crystal shape, but showing little or no effect on the 'thermal' spots which bracket the $\bar{2}01$ Laue reflection.

Plate XI shows a variety of effects, using other crystals.

g. 1. Laue photographs of beryl at settings 1° apart, showing transitory appearance of split reflections due to characteristic radiation, superimposed on reflections of general radiation in a different order.

g. 2. Rotation photograph of beryl, showing narrow and broad reflections obtained from a thin plate as it rotates. In some instances, spots of different shapes are superimposed on each other, owing to the lack of resolution in this method.

g. 3. Rotation photographs of benzil (small prism, height vertical, $1{\cdot}5 \times$ width) showing effect of non-collimation of incident X-ray beams from targets of various shapes and definitions.

g. 4. Laue photograph of large distorted diamond plate (D 19 in Phil. Trans. Roy. Soc., Ser. A, 1934, vol. 232, p. 469) placed for Bragg reflection from (111) face; showing effect of crystal shape and distortion.

g. 5. Laue photograph of small piece of diamond chipped off corner of specimen D 19, showing asterism and orientated distortion (cf. pl. X, figs. 3 and 5).

g. 6. Laue photograph of square diamond plate, showing effect of crystal shape and beam divergence. Spots near to undeviated incident beam are small, whereas asterism involves maximum distortion of spots for which θ is small.

g. 7. Laue photograph of very small crystal of bröggerite, cube axis parallel to incident X-ray beam, showing effect of partial disorientation of crystallites (asterism and very slight spiralling); also showing sharper spots due to characteristic radiation.

g. 8. Rotation photograph of same crystal as in fig. 7, cube axis vertical, photograph film parallel to X-ray beam, showing spreading of reflections (especially back reflections) circularly about forward and back directions of incident beam, due to partial disorientation of crystallites.

MINERALOGICAL ABSTRACTS

(Vol. 9, No. 7, September, 1945.)

New Minerals

UBNIKOVA (O. M.) Шубникова (О. М.). Новые минеральные виды и разновидности, открытые в 1938 г.—*New minerals* [*species and varieties*] *discovered in 1938*. Труды Инст. Геол. Наук, СССР, 1940, no. 31 (Мин.-Геохим. Сер., no. 6) [Trans. Inst. Geol. Sci., U.S.S.R., no. 31 (Min.-Geochem. Ser., no. 6)], pp. 31–62, 9 figs.

ontinuation of previous lists of new minerals [M.A. **6**–51; **7**–9, 58; **8**–2]. From literature of 1938 (with some earlier) forty-two are collected of which eleven from the U.S.S.R. L. J. S.

TONOV (N. Kh.) Платонов (Н. Х.). *New mineral formations in the course of contact metamorphism of oil-bearing marls*. Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 33, pp. 358–362, 6 figs.

ocene bituminous marl lightly metamorphosed by an intrusion of trachyte Mt. Syuereshe, Caucasus, contains 3·75 % of organic matter. Of this 1·70 % paraffin soluble in chloroform, and the insoluble portion contains C 90·20, 75, N 0·97, S 2·16, O 3·92, ash 1·59. The latter, named *chirvinskite*, differs n anthraxolite in containing more S than N. It has a bright vitreous lustre, k streak, sp. gr. 2·10–2·13, H. 3½–4, and gives a hexagonal X-ray pattern of p lines, different from shungite and anthraxolite, but resembling artificial oke. The material represents a stage in the alteration of oil through bitumen raphite. L. J. S.

TASSEL (René). *Occurrence de minéraux sulfatés récents sur des schists de Mousty, à Franquenies*. Bull. Mus. Hist. Nat. Belgique, 1944, vol. 20, no. 16, 24 pp., 1 pl., 1 text-fig.

ellow efflorescences (previously thought to be sulphur) on Cambrian shales ist mainly of a new species named *franquenite*. Minute hexagonal scales 5 μ across, 2 μ thick) have ω 1·531, ϵ 1·494, sp. gr. 1·87–1·94. Analysis I, ula $2(Mg,Fe)SO_4.6(Fe,Al)OHSO_4.41H_2O$. It is slowly soluble in cold water. hydration curve is given; 28·2 % H_2O is lost at 110°. This new mineral is pared with slavikite [M.A. **3**–365]. Intermixed with it are fine fibres of ferrite (?) (n' 1·530, n'' 1·573). On the shales there are also gypsum and e efflorescences of pickeringite (anal. II; n 1·475–1·482, $\gamma : c = 36–37°$), pickeringite (III; n 1·478–1·488, $\gamma : c = 36–38°$), and melanterite (n 1·472–, $\gamma : c = 54–61°$).

SO_3.	Al_2O_3.	Fe_2O_3.	FeO.	MnO.	MgO.	$(Na,K)_2O$.	H_2O.	Total.
32·77	5·51	14·84	1·00	—	4·23	n.d.	40·69	99·04
36·31	11·72	trace	0·27	0·42	5·34	—	45·66	99·72
34·66	9·07	0·50	7·48	0·21	2·84	—	45·24	100·00

L. J. S.

E (André). *L'apatélite de Meillet*. Bull. Soc. Franç. Min., 1942, vol. 65, p. 39–42.

able, earthy, yellow nodules from Oligocene limestone at La Souys, near eaux, consist of finely crystalline material (uniaxial negative, probably

rhombohedral) with intermixed gypsum. Analysis gave SO_3 35·15, Fe_2O_3 52·9 H_2O 11·38, SiO_2 and Al_2O_3 traces, formula $3Fe_2O_3.4SO_3.6H_2O$, agreeing with recalculation of A. Meillet's 1841 analysis (H_2SO_4 42·90, Fe_2O_3 53·30, H_2O 3· of apatelite from the Paris basin. Similar material from the Paris basin descri by A. Lacroix as apatelite (Min. France, 1910, vol. 4, p. 246) gave on anal by F. Pisani SO_3 29·7, Fe_2O_3 40·0, Al_2O_3 11·0, H_2O 19·2 with the form $(Fe,Al)_2(OH)_4SO_4.H_2O$ or $5Fe_2O_3.2Al_2O_3.7SO_3.21H_2O$; this is now named *pseud apatelite*. Apatelite together with gypsum has been formed by the action copiapite on limestone; and pseudo-apatelite from copiapite, halotrichite, a limestone. L. J. S.

Warren (H. V.) & Peacock (M. A.). *Hedleyite, a new bismuth telluride fr British Columbia, with notes on wehrlite and some bismuth-tellurium alloy* Univ. Toronto Studies, Geol. Ser., 1945, no. 49, pp. 55–69, 6 figs.

Hedleyite is an unstable solid solution near $Bi_2Te_3.Bi_5$, found with nat bismuth, joseite, and gold at Good Hope mineral claim, Hedley, Osoyoos min division. Occurs in plates with easy basal cleavage giving flexible folia; hardne 2 (B), sp. gr. 8·68–8·93, 8·91; metallic, tin-white with iron-black tarnish. Th rhombohedral unit cell with a 39·68 Å., α 6° 26½′ (from hexagonal a 4·46, c 118·8 Å contains approximately $Bi_{14}Te_6$; a marked rhombohedral substructure h a 3·248 Å., α 86° 42½′ (from hexagonal a 4·46, c 5·94 Å.) with one atom per ce Analyses by G. S. Eldridge gave Bi 80·60 (81·55), Te 18·52 (17·60), S 0·12 (0·04 totals 99·24 (99·19). Separates into Bi and a solid solution near Bi_2Te_3. (wehrlite) on fusion and recrystallization in vacuum. The stable alloy Bi_2Te_3. (not BiTe) gives the X-ray powder pattern of wehrlite (Harcourt [M.A. **8**–280 and yields the rhombohedral substructure cell with a 3·236 Å., α 86° 08½′ (fro hexagonal a 4·42, c 5·97 Å.) with one atom per cell. M. A. P.

Gruner (John W.). *Groutite, $HMnO_2$, a new mineral of the diaspore-goethite grou* Amer. Min., 1945, vol. 30, p. 169 (abstract).

Fine groups of wedge- or lens-shaped crystals with rounded faces occur vugs in iron ore of the Cyuna range, Minnesota. They are jet-black with brig submetallic to adamantine lustre and dark brown streak. The crystals a flattened on (001) and the prism zone is striated vertically; cleavage (010) perfe (100) good; $a:b:c = 0·4262:1:0·2663$; unit cell a 4·56, b 10·70, c 2·85 A. Sp. g 4·14; strongly pleochroic. [The brief abstract makes no mention of the distinctio from manganite.] L. J. S.

Preez (J. W. du). *A thermal investigation of the parkerite series.* Ann. Uni Stellenbosch, 1944, vol. 22, sect. A, pp. 97–102, 2 pls., 1 text-fig.

Re-examination of parkerite from Insizwa, South Africa [M.A. **6**–440; **9**– shows the presence of bismuth and lead in almost equal proportions. *Bismu parkerite* $Ni_3Bi_2S_2$ (m.p. 686°) and *lead-parkerite* $Ni_3Pb_2S_2$ (m.p. 792°) were pr pared by fusing together the elements in an atmosphere of hydrogen. Ni_3Bi_2 and solid solutions containing up to 50 % $Ni_3Pb_2S_2$ were obtained as go crystals with lamellar twinning; beyond this there is a small gap in the seri and solid solutions of lead-rich parkerite are usually only stable at high temper tures. [M.A. **9**–89.] L. J. S.

LSON (N. W.). *Geology of the Monarch cinnabar mine, Transvaal, South Africa.* Bull. Inst. Mining Metall. London, 1945, no. 470, 24 pp., 2 pls., 7 text-figs.

'he ore is disseminated along bands in carbonated schists in the Letabe district, . Transvaal, and consists of cinnabar, haringtonite often in graphic intergrowth h native gold, stibnite, fahlerz, corynite, pyrite, and native mercury, with the ondary minerals cuprite, chessylite, malachite, terlinguaite, and eglestonite. *aringtonite'*, from Harington Kop, resembles cinnabar and guadalcazarite h a blackish tinge, submetallic lustre, and cinnabar-red streak, but contains excess of sulphur (S: Hg = 1·2) with spectroscopic traces of Cu, Zn, Sn, Sb, It is optically anisotropic. L. J. S.

IMARAENS [= GUIMARÃES] (Caio Pandiá). *Calogerasita, um novo mineral da família dos tantalatos.* Mineração e Metalurgia, Rio de Janeiro, 1944, vol. 8, pp. 135–136, 3 figs. Anais Acad. Brasileira Ciencias, 1944, vol. 16, pp. 255–260, 2 figs.

'his mineral [M.A. **9**–7] was found in pegmatite worked for tantalite on Giz (Alto do Giz), Equador district, on the border of Rio Grande do Norte and aiba. A small yellow crystal is hexagonal of prismatic habit with the forms 01), (10$\bar{1}$0), and (11$\bar{2}$0), good basal cleavage, and irregular fracture. Sp. gr. 0–7·30, H. 6½–7, *n* 2, birefringence 0·041–0·044, uniaxial, negative. It shows rilliant golden-yellow fluorescence in ultra-violet rays. Analyses gave Ta_2O_5 30–73·80, Al_2O_3 26·10–26·20, corresponding with $3Al_2O_3.2Ta_2O_5$. The mineral elated to simpsonite [M.A. **7**–369]. L. J. S.

JGH (Frederick H.). *Tantalite—a Cinderella among strategic minerals.* Nat. Hist. (Amer. Mus. Nat. Hist.), 1945, vol. 54, pp. 102–109, 16 figs.

popular account of mining for tantalite in the pegmatites of northern Brazil. ociated minerals are beryl, columbite, microlite, manganotantalite, tapiolite, psonite, &c. Simpsonite [M.A. **7**–369, compare preceding abstract] from Giz in Rio Grande do Norte forms yellow-brown or white, well-developed crystals or more inches across; they are hexagonal of short-prismatic habit with ns *c a b p*. Simpsonite has also been found on the neighbouring Mamoes hill Vassoeira plain. L. J. S.

NTON (T. L.). *Conchilites.* Trans. Roy. Soc. Canada, 1944, ser. 3, vol. 38, sect. 4, pp. 97–103, 4 pls.

'he draining of Finlayson lake, Rainy River district, Ontario, uncovered a r of glaciated mineralized schist with scores of adhering shell-shaped objects ch to 1 yard in diameter and up to 3 inches high. These are concretions of onite and goethite, sometimes with magnetite and manganite, and are named *chilites*. M. A. P.

RZAEV (P. M.) Мурзаев (П. М.). *On saltspar and its origin.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 33, pp. 306–307.

ranular rock-salt usually shows a grain-size of only a few millimetres. Gigantic talline halite in cleavable masses up to 50 cm. or more is called saltspar. In Artemovskoye deposit of Permian age in the Donetz basin lenticular masses altspar occur in the granular rock-salt. Cubical cavities, up to 2–3 cm., filled brine and air are frequent. Its origin has been supposed to be due to

dynamo-metamorphism or to recrystallization in sink-holes: more probably is an original crystallization in the deeper and stiller waters of a lagoon.

L. J. S.

Growth and Corrosion of Crystals

Stranski (I. N.). *Über die Thomson–Gibbssche Gleichung und über die sogenannte Theorie der Verwachsungskonglomerate.* Zeits. Krist., 1943, vol. 105, pp. 94–123, 15 figs.

A derivation of the Thomson–Gibbs equation and a detailed criticism of the conclusions drawn by D. Balarew [M.A. **6**–64, 468]. F. A. B.

Laue (M. *v.*). *Der Wulffsche Satz für die Gleichgewichtsform von Kristallen.* Zeits. Krist., 1943, vol. 105, pp. 124–133, 1 fig.

A general proof of Wulff's principle was first given by Liebmann in 1914. An alternative derivation based on thermodynamics is derived and discussed.

F. A. B.

Roginsky (S. Z.) & Todes (O. M.) Рогинский (С. З.) и Тодес (О. М.). *Distribution laws in relation to dispersion of growing crystals.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1940, vol. 27, pp. 677–680, 7 figs.

Summary of a previous paper [M.A. **8**–261]. M. H. H.

[Volfkovich (S. I.) & Glazova (T. V.)] Вольфкович (С. И.) и Глазова (Т. В.). Киномикроскопическое исследование процессов кристаллизации нитратов. Доклады Акад. Наук СССР, 1943, vol. 41, pp. 346–347.

Wolfkovich (S. I.) and Glasova (T. V.). *Microcinomatographic investigation of the processes of crystallization of nitrates.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1943, vol. 41, pp. 332–333.

The crystallization of NH_4, K, Na, and Ca nitrates from saturated solution or from melts on a heated microscope stage was registered on a film at the rate of 64 pictures per second. Size and aggregation of the crystals, on which the compactness, coalescence, and hygroscopicity of the material depend, are noted for different conditions of crystallization. Transformation of cubic to rhombohedral ammonium nitrate at 125° C. is accompanied by a contraction in volume and of the latter at 84·5° by an increase, followed at 32·5° by another contraction. In addition to the five known polymorphs of ammonium nitrate, a new form with a temperature range of 44–57° is noted. Transformation of orthorhombic to rhombohedral KNO_3 takes place on contact of the latter with the former.

L. J. S.

[Lemmlein (G. G.)] Леммлейн (Г. Г.) Laemmlein (G. G.). *Distortions of habit of quartz crystals depending on their position during growth.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 33, pp. 415–418, 1 fig.

Crystals of quartz that have grown with the principal axis in a vertical position usually show a symmetrical development of the positive and negative rhombohedra, and *s* and *x* faces are less often present. Crystals grown in an inclined position usually show an irregular development of the faces, the larger faces being on the under side, and *s* and *x* faces are more frequent. [M.A. **7**–557.]

L. J. S.

GORIEV (D. P.). *New observations on the results of gravitational shifting of crystals in veins of Alpine type in the near-polar Urals.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1944, vol. 44, pp. 198–200, 2 figs.

ock-crystal with a certain distribution of enclosures and encrustations of olite and prochlorite give indications of the direction in which the foreign icles fell on the growing crystal. From this the original orientation of the can be deduced. [M.A. 7–44, 212, 557.] L. J. S.

ER (L. C.). *The growth of crystals of potassium sodium tartrate.* New Zealand Journ. Sci. Techn., Sect. B, 1944, vol. 25 (for 1943), pp. 62–64.

arge crystals (more than 200 grams) of Rochelle salt for piezoelectric work e grown from solutions saturated at 30–40° C. by allowing the air in a small lated room to cool slowly ($\frac{1}{2}$–1° C. per 24 hours) during 2–4 weeks. A seed tal is suspended by human hair in a beaker of $\frac{1}{2}$–3 litres, and evaporation is rented by a thin layer of paraffin-oil on the surface of the solution. If cooling o rapid, supersaturation causes a shower of minute crystals. Crystal plates ch thick and 2–3 inches in the direction of the *b* and *c* axes) were grown by rting an orientated seed crystal between glass plates. L. J. S.

LMERS (Bruce). *Non-parallelism of lattice planes in tin coatings on steel.* Nature, London, 1940, vol. 146, p. 493.

urvature in the tin crystals is probably due to a greater concentration of iron the tin-iron interface. The effect probably occurs in other zoned crystals. M. H. H.

THCOTT (L.) & THOMAS (D. E.). *Dendritic structures. Part I. The influence of crystal orientation.* Journ. Inst. Metals, 1939, vol. 65, pp. 205–216, 4 pls., 4 text-figs.

lloys of copper with Mn, P, Al, Sn, and Zn often develop a columnar or dritic structure along [100] and parallel to the direction of growth; the lines posing the dendritic structure are traces of (100) planes. A simple mechanical hod for determining the orientation of a crystal from the traces of its cube es on an etched surface (as shown by the dendritic structure) has been devised gives results in agreement with those obtained by X-ray methods [cf. Mag. **26**–147]. M. H. H.

RONEL (Giorgio). *Azione dei pentossidi del V gruppo sulla cristallizzazione della silice in tungstato sodico fuso.* Zeits. Krist., 1942, vol. 104, pp. 261–264.

Whereas tridymite crystallized from silica melts in fused sodium tungstate at ° C., the presence of small amounts of P_2O_5, V_2O_5, or As_2O_5 in the fusion lts in the formation of cristobalite. F. A. B.

A (Tôkiti) & ISIHARA (Yosihiro). *Effect of the addition of salts on the crystal growth of alumina.* Journ. Soc. Chem. Ind. Japan, 1940, vol. 43, supplement, pp. 71B–72B.

A (Tôkiti) & HASEGAWA (Masatosi). *Effect of the addition of salt vapour on the synthesis and the crystal growth of spinel.* Ibid., pp. 72B–73B.

xperiments on the mineralizing action of alkali and alkaline earth halides. M. H. H.

Copisarow (Alcon C.) & Copisarow (Maurice). *Silica and the Liesegang phenomenon.* Nature, London, 1942, vol. 149, p. 413.

Aqueous solutions of water-glass covered with an excess of concentrated H developed horizontal bands, which were more closely packed for more dil solutions. F. A. B.

Schneiderhöhn (Hans). *Mineraleinschlüsse in Erzmineralien.* Neues Jah Min. Monatshefte, Abt. A, 1943, pp. 1–22.

A classification of the different types of enclosures in ore-minerals is given four main classes with 18 sub-classes: (1) accidental impurities taken up du crystal growth; (2) original oriented and exsolution intergrowths; (3) produ of metamorphism; (4) products of secondary alteration. Many examples a quoted. L. J. S.

Frondel (C.), Newhouse (W. H.), & Jarrell (R. F.). *Spatial distribution minor elements in single-crystals.* Amer. Min., 1942, vol. 27, pp. 726–74 4 figs.

Crystal growth is considered in connexion with the inclusion of foreign materi by preferential adsorption on certain faces (edges and corners), giving within t crystal 'face-loci' (i.e. pyramids with the face as base and the apex at the cent of the crystal) also 'form-, edge-, and corner-loci'. Zonal banding is also co sidered, and many examples are quoted from the literature of the heterogeneit of crystals. Polished sections cut in successive slices parallel to a cube face galena when etched with dilute HNO_3 show darkened areas corresponding the octahedral face-loci. Spectrographic analysis shows these areas to be rich in Ag and Si; and Cu, Fe, Al, Cr, Ba, Sr, Ca, Mg also show some variations. I calcite no connexion could be traced between the distribution of Fe, Cu, Mn, A Sr, Mg and the morphology or colour of the crystals. L. J. S.

Schwab (Georg-Maria). *Orientierte Bildung von β-Silberjodid auf Silberbromi* Naturwiss., 1943, vol. 31, p. 322.

Cubic crystals of AgBr placed in a dilute solution of KI become coated wit hexagonal β-AgI [iodyrite], the basal plane of the latter being parallel to a octahedral plane of the former, for which the spacings are 2·88 and 2·81 respectively. L. J. S.

Willems (J.). *Über orientierte Aufwachsungen von Phenol auf verschiedene Mineralarten.* Naturwiss., 1941, vol. 29, pp. 319–320.

—— *Zur Chemie der orientierten Verwachsung von Kristallen organischer Verbin dungen. I. Über die orientierte Aufwachsung von Anthrachinon auf Antimon* Ibid., 1943, vol. 31, pp. 208–209.

—— *II. Über die Bedeutung der Wasserstoffbrücke für die organischen Verbindunge* Ibid., pp. 232–233, 3 figs.

—— *IV.* Ibid., pp. 301–302.

Preliminary notes of papers abstracted below. L. J. S.

ILLEMS (J.). *Über orientierte Verwachsungen von Phenolen mit den Carbonaten der Kalkspatreihe und Natriumnitrat. Ein Beitrag zur Kenntnis der Bedingungen für die regelmäßige Verwachsung von Kristallen organischer Verbindungen.* Zeits. Krist., 1943, vol. 105, pp. 53–68, 2 figs.

Orientated overgrowths of phenols like α-hydroquinone on crystals of carbonates the calcite series can be readily obtained, but not with naphthazarin, α-glucose, cinic or salicylic acid. The difference of behaviour is attributed to the ference in the hydrogen bonding of the hydroxyl groups in the two types of ganic compound used as overgrowths. F. A. B.

ILLEMS (J.). *Über die orientierte Verwachsung von Hydrochinon mit Glimmer.* Zeits. Krist., 1943, vol. 105, pp. 144–148, 2 figs.

— *Über die orientierte Aufwachsung von Urotropin auf Gips. Ein Beitrag zur Kenntnis der für die orientierte Aufwachsung von Kristallen organischer Stoffe maßgebenden Kräfte.* Ibid., pp. 149–154, 3 figs.

— *Über die orientierte Aufwachsung von Hydrochinon auf Schwerspat und Cölestin.* Ibid., pp. 155–156.

Acicular rhombohedral (C_{3i}^2) crystals of hydroquinone from a solution in nzene or chloroform are deposited in regular growth on micas, baryte, and estine. The orientations are stated and the lattice spacings compared.

L. J. S.

IN-PIAW (Choong) = SHÊNG-PIAO (Chung). *Orientation of the etching figures of quartz.* Nature, London, 1944, vol. 154, p. 464, 1 fig.

Surfaces of Brazilian quartz cut normally to the optic axis yield triangular h pyramids with hydrofluoric acid, orientated so that the edges between jacent pyramid faces are parallel to the mechanical not the electric axes of artz. This contradicts earlier observations and probably accounts for the low lue of the piezoelectric constant obtained by A. de Gramont (1935), who relied incorrectly orientated etch figures for his determination of the directions of e electric axes. A recent value of the piezoelectric constant of quartz is $)5 \times 10^{-8}$ C.G.S. units (Langevin, 1939). F. A. B.

IN-PIAW (Choong) = SHÊNG-PIAO (Chung). *Influence of ultra-violet radiations on the etching of quartz.* Nature, London, 1944, vol. 154, pp. 516–517.

When a plate of quartz normal to the optic axis is etched with hydrofluoric d the portion of the surface exposed to ultra-violet radiation becomes trans- rent, whereas that portion not so exposed remains matt. The etch triangular ramids are found to be notably flattened in the transparent irradiated portion d also changed in orientation by 15°. This distinction cannot, however, be served for quartz plates cut in other directions or for fused silica plates. It is ggested that the phenomenon may be evidence of the modification of the rstalline structure of quartz by the ultra-violet radiation. F. A. B.

NLON (F. N.). *The etch figures of basal sections of quartz. Their use in the orientation of waterworn crystals.* Journ. Roy. Soc. New South Wales, 1944, vol. 77 (for 1943), pp. 40–51, 2 pls., 9 text-figs.

Basal sections of quartz etched by hydrofluoric acid were examined by oblique

illumination on the rotating stage of a microscope. The position of the sect for maximum reflection varies with duration of etching. By observing t positions of maximum illumination of an unknown section during etching, orientation can be obtained to within a few degrees, but the process is long a tedious. F. A. B

Delavault (Robert). *Action de l'acide fluorhydrique sur la muscovite.* Co Rend. Acad. Sci. Paris, 1942, vol. 215, pp. 582–584, 1 fig.

Two forms of etch-figures on cleavages of muscovite and phlogopite are figu one related to the crystal-structure, and the other due to irregularities of gro or to the presence of impurities. L. J. S.

Delavault (Robert). *Figures de corrosion de la muscovite.* Compt. Rend. A Sci. Paris, 1944, vol. 218, pp. 158–159, 1 fig.

Different forms of etch-figures were obtained with different reagents: H HF+NaF, HF+H_2SiF_6, HF+H_2SO_4, KNO_3, NaOH, &c. L. J. S.

Zedlitz (Otto). *Goniometrische Untersuchungen der Lösungs- und Ätzerscheinung an einem Beryllkristall von Minas Geraes, Brasilien.* Zentralblatt M Abt. A, 1941, pp. 98–108, 9 figs.

Good photomicrographs are given of etch-figures on a corroded crystal of ge beryl, and the light-figures reflected by them are well illustrated. L. J. S.

Chemical Crystallography

Wells (A. F.). *Finite complexes in crystals: a classification and review.* Ph Mag., 1940, ser. 7, vol. 30, pp. 103–134, 13 figs.

In crystals having more than one kind of bonding (e.g. ionic and homopola or homopolar and van der Waals), finite or non-finite groups within which th bonding is of one kind may often be distinguished. A classification of fini groups of this kind has been devised, arranging them according to the numb and linkings of the (structurally) principal atom present. The occurrence some types of finite complex is reviewed, and suggestions are made as to th probable structure of the heteropoly acids. [M.A. 8–258.] M. H. H.

Strunz (H.). *Isotypie und Isomorphie.* (*I. Mitteilung zur Kristallchemie*). Natu wiss., 1942, vol. 30, pp. 526–531.

Machatschki (F.). *Bemerkung zu den Artikel „Isotypie und Isomorphie" vo H. Strunz . . .* Ibid., 1943, vol. 31, p. 43.

Strunz (H.). *Zur Bemerkung von F. Machatschki . . .* Ibid., pp. 93–94.

The first paper discusses with examples the terms isomorphism and isotypism in the latter there is no formation of mixed crystals. The term 'diadochism' i introduced to express the interchangeability of ions without changing th crystalline form. The second note criticizes this distinction between isomorphis and isotypism, and considers the term 'diadochism' to be unnecessary. [M.A 8–343.] L. J. S.

CHATSCHKI (F.). *Steenstrupin ist kein Silikat vom Formeltypus Apatit.* Naturwiss., 1943, vol. 31, pp. 438–439.

Criticism of H. Strunz [M.A. **8**–369]. L. J. S.

L (W. L.), FAUST (G. T.), & HENDRICKS (S. B.). *Polymorphism of phosphoric oxide.* Journ. Amer. Chem. Soc., 1943, vol. 65, pp. 794–802, 6 figs.

phase diagram is given of the three solid, two liquid, and gaseous forms. agonal P_2O_5 has ω 1·469, ϵ 1·471, d 2·283–2·317; orthorhombic, α 1·545, ·578, γ 1·589. 2V about 65°, negative; tetragonal (?), ω 1·599, ϵ 1·624, 737–3·05 (calc. 2·89). L. J. S.

ULMAN (James H.) & SCHUMB (Walter C.). *The polymorphism of arsenious oxide.* Journ. Amer. Chem. Soc., 1943, vol. 65, pp. 878–883, 2 figs.

olubility determinations in HCl of the monoclinic and cubic forms of As_2O_3 w that the former is stable with respect to the latter from 2° to the melting- nt, and that there is an enantiotropic relation between them with transition perature at −13°. Water vapour at 180° accelerates the transformation of cubic form to the monoclinic. There is no evidence for the existence of three er supposed forms. L. J. S.

USTINSKY (A. F.) & CHENTZOVA (L. G.) Капустинский (А. Ф.) и Ченцова (Л. Г.). *Heats of transformation in the system of wurtzite-sphalerite and cinnabar-metacinnabarite.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 30, pp. 489–490.

he heats of solution of blende and wurtzite in 33 % HCl and of cinnabar and acinnabarite in 38 % K_2S are 17·4, 50·2, 12·4, and 16·5 cal. per gram ectively; hence the heats of transformation from wurtzite to blende and n metacinnabarite to cinnabar are respectively 3·19 and 0·95 kg.-cal. per mol. M. H. H.

H (W. A.). *Die Bildungswärmen einiger mineralischer Carbonate.* Journ. Prakt. Chem., 1941, vol. 158, pp. 117–124.

eats of formation from the oxide and CO_2 were determined as: for cerussite , witherite 61, strontianite 55, calcite 42·5, aragonite slightly higher, mag- te 23, smithsonite 16·9, rhodochrosite 15, chalybite 16, malachite 13·8, sylite 20·9, $CdCO_3$ 19, $CoCO_3$ 17–20, $NiCO_2$ about 10 kg.-cal. per mol. L. J. S.

OPOV (N. A.) & STUKALOVA (M. M.) Торопов (Н. А.) и Стукалова (М. М.). *Replacement of sodium in crystals of β-alumina with calcium, strontium and barium.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1940, vol. 27, pp. 974–977.

he β-alumina series $RO.6Al_2O_3$, where RO may be Na_2O, K_2O, Rb_2O, CaO, or BaO, are all isostructural, with hexagonal symmetry and similar lattice meters; they give base-exchange under suitable conditions, the alkali salts g readily obtained by fusion of the barium salt with alkali carbonate or ride and the alkaline earth salts by fusion of the sodium salt with an alkaline h chloride. M. H. H.

Brun (Edmond) & Jaffray (Jean). *Sur les points de transition des cristaux de sulfate de cuivre pentahydraté.* Compt. Rend. Acad. Sci. Paris, 1943, vol. 2[illegible] pp. 371–372, 1 fig.

The cubic dilatation of $CuSO_4.5H_2O$, determined in toluene with a dilatometer, shows sharp breaks at 28·90° C. (36×10^{-5} before, 11×10^{-5} after), 34·85° ($49-15\times10^{-5}$), and 53·70° C. ($106-36{\cdot}5\times10^{-5}$). L. J. S.

Fedoroff (B.). *Contribution à l'étude des sulfates simples et doubles de quelques métaux de la série magnésienne.* Ann. Chim. Paris, 1941, ser. 11, vol. [illegible] pp. 154–214, 4 pls., 17 text-figs.

Demassieux (N.) & Fedoroff (B.). —— *II. Sulfates de: Cd^{++}, Zn^{++}, Mn^{++}, Fe^{++} et les sulfates doubles de ces métaux avec le potassium.* Ibid., pp. 215–[illegible] 11 figs.

The electrical properties of solutions of sulphates of Mg, Cu, Co, Ni, Zn, Cd, Mn″, Fe″ and of their double salts with potassium sulphate were determined. Dehydration curves and X-ray diagrams are given for the solid salts. L. J. S.

Toropov (N. A.) & Konovalov (P. F.). *Solid solutions of calcium and strontium orthosilicates.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1943, vol. 4[illegible] pp. 155–157, 2 figs.

Mixtures of $CaCO_3$ and $SrCO_3$ in various proportions with SiO_2 were fused in the electric arc. They form a continuous series of solid solutions from Ca_2SiO_4 (sp. gr. 3·28, α 1·717, γ 1·735) to Sr_2SiO_4 (sp. gr. 3·84, α 1·727, γ 1·756). L. J. S.

Pobeguin (*Mlle* Thérèse). *Description sommaire des hydrates d'oxalate de Ca.* Compt. Rend. Acad. Sci. Paris, 1943, vol. 216, pp. 500–501.

Lecomte (Jean), Pobeguin (*Mlle* Thérèse), & Wyart (Jean). *Sur les sels de calcium de l'acide oxalique. (Courbes de déshydratation. Étude aux rayons X. — aux rayons infrarouges.)* Ibid., pp. 808–810.

Dehydration curves, X-ray powder data, and infra-red bands are given for monoclinic $CaC_2O_4.H_2O$ [whewellite] and for three forms of $CaC_2O_4.3H_2O$. L. J. S.

Saratovkin (D. D.) & Savintzev (P. A.) Саратовкин (Д. Д.) и Савинцев (П. А.). *Formation of liquid phase at the site of contact between two crystals composing an eutectic pair.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 3[illegible] pp. 304–305.

Pieces (pea-sized) of Pb in contact with Sb, Bi, or Sn showed melting when raised to the eutectic temperature. Similar results were obtained with various organic compounds. L. J. S.

Colour of Minerals

Uklonsky (A. S.) Уклонский (А. С.). *Metachromatism of minerals.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 32, pp. 209–312.

The term metachromatism is suggested for the differences in colour seen in various illuminations, with or without filters. A list is given contrasting the colours shown by various minerals in daylight and under a mercury-vapour lamp. L. J. S.

VRUSEVICH (B. A.) Гаврусевич (Б. А.). *On the coloration of some Ural corundums.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 31, pp. 686–688.

The constituents responsible for the colours of corundum are discussed with cial reference to the corundums of Vishneviye Gory and Kishtym; these ge from white through blue, green, or brown to black, and are largely allo-omatic. Fe″ and Ni appear to be responsible for green, Fe‴ and Mn for brown, for blue tints. Eight analyses are given. M. H. H.

IGORIEV (D. P.) & KOTULSKY (A. V.) Григорьев (Д. П.) и Котульский (А. В.). *Diagram showing the dependence of coloration of magnesian-ferriferous micas on the content of iron oxides.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 31, pp. 691–693, 1 fig.

ron-free phlogopites are colourless; both Fe″ and Fe‴ produce yellow and wn colours, deepening to black with the percentage of iron; the presence of and Fe‴ together produces a darker colour than either alone. It is suggested t the names phlogopite, biotite, and lepidomelane should be applied respec-ely to pale specimens translucent in sheets ½–1 mm. thick, to dark brown cimens still translucent in thin sheets, and to black opaque specimens pectively. M. H. H.

AVRUSEVICH (B. A.) & SARAPULOV (F. Y.)] Гаврусевич (Б. А.) и Сарапулов (Ф. Я.).—GAVRUSEVICH (B. A.) and SARAPULOV (Th. J.). *On the change of colour and optical properties of beryls on heating.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 31, pp. 775–778.

On heating to temperatures below 600° C., blue and green beryls tended to ome lighter in colour, but to a very variable extent. Doelter's conclusion t aquamarines lose their colour while emeralds do not was confirmed. The active indices were unchanged; between 600° and 800° C. the refractive ices fell, and the beryls all became opaque. M. H. H.

INZERLING (E. V.)] Цинзерлинг (E. B.) ZINSERLING (E. V.). *Quartz colouring as dependent on its twinning capacity under $\alpha \rightarrow \beta$ conversion.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 33, pp. 368–369.

moky quartz and some colourless crystals do not develop twinning or change sting twin boundaries by heating or mechanical deformation. Such colourless stals become dark coloured on exposure to X-rays. Other colourless crystals vhich twinning can take place are only slightly coloured by X-rays; or if the nning is irregular they are coloured in spots and streaks. The presence of ouring impurities hinders the capacity for twinning. [M.A. **9**–144.] L. J. S.

EMMLEIN (G. G.). *Ability of crystalline quartz and of glass melted from it to take colour on irradiation.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1944, vol. 43, pp. 234–235.

Colourless quartz from various localities exposed to radium or X-rays usually uires a violet colour, rarely greyish-brown; but some specimens remain urless or nearly so. Glass behaved in the same manner as the crystal from ch it was fused. Glass from smoky-quartz gave an intense violet colour. Pale thyst acquired an additional faint smoky colour, and its glass took a weak ish-violet colour. This suggests the presence of some foreign colouring ter, rather than the separation of colloidal silicon. [M.A. **6**–265.] L. J. S.

Jayaraman (N.). *A chemical study of the Nellore beryl and the cause of its colouration.* Journ. Indian Inst. Sci., 1940, vol. 23A, pp. 30–35.

Analyses of I rich blue, II pale blue, III apple-green, IV greenish-yellow, and V colourless beryls from Nellore [M.A. **4**–85]. The last agrees with the formula of Jakob [M.A. **8**–91] $6(BeO,FeO,Na_2O).2(Al_2O_3,Fe_2O_3).12SiO_2.H_2O$, and the others with the same but with $\frac{1}{2}H_2O$. Heated at 500° C. for 5 hours the green specimens changed to blue, while the others showed no change. The amounts of Fe_2O_3 and FeO after this heating are given at the end of the following table. Blue colour is due to Fe_2O_3 and green to FeO.

	SiO_2.	Al_2O_3.	BeO.	Fe_2O_3.	FeO.	Na_2O.	H_2O.	Total.	Sp. gr.	Fe_2O_3.	FeO.
I.	66·69	17·57	12·58	1·25	0·35	0·63	0·82	99·89	2·7192	1·37	0·17
II.	66·89	17·66	12·73	1·09	0·34	0·42	0·73	99·86	2·7153	1·20	0·24
III.	66·35	18·37	12·29	0·43	1·46	0·29	0·88	100·07	2·7061	1·75	0·39
IV.	66·21	18·34	12·26	0·73	1·24	0·26	0·89	99·93	2·7088	1·79	0·42
V.	66·48	18·62	12·55	0·17	0·39	0·35	1·58	100·14	2·6998	—	—

L. J. S.

Jayaraman (N.). *Supplement to the paper on blue quartz.* Journ. Indian Inst. Sci., 1940, vol. 23A, pp. 28–29. [M.A. **8**–136, 526.]

A reply to criticisms. It has been suggested that when blue quartz is heated the colour is not really lost, but masked by white reflections from cracks developed by the heating; but no such cracks could be detected under the microscope. The colour is not dependent on the size of the enclosed rutile needles, since in colourless specimens these are smaller than in coloured ones. L. J. S.

Raymond (Percy E.). *The pigment of black and red sediments.* Amer. Journ. Sci., 1942, vol. 240, pp. 658–669.

Black shales are abundant amongst Palaeozoic rocks, although marine black muds are now of limited distribution. It is suggested that the colour of earlier Palaeozoic shales is due to the chitinous remains of tribolites and graptolites, and of later Palaeozoic shales to vegetable matter. The red pigment of many soils of warm moist regions is shown by X-rays to be haematite. It is suggested that hydrous ferric oxide (rather than ferric hydroxide) was precipitated from ferric nitrate and ammonia produced by nitrifying bacteria. L. J. S.

Ehret (William) & Greenstone (Arthur). *Red zinc oxide.* Journ. Amer. Chem. Soc. 1943, vol. 65, pp. 872–877, 6 figs.

Red ZnO is prepared by heating white ZnO with ammonium salts, preferably the nitrate; the colour is due to a slight excess of zinc (about 0·02 %). [M.A. **5**–257, **6**–57.] L. J. S.

Williams (Herbert E.). *The cause of the variation of the colour of crystals of commercial sodium and potassium ferrocyanide* [*cyanoferrate* (*II*)]. Journ. Chem. Soc. London, 1943, pp. 223–227.

The crystals vary in colour from light yellow to amber, and they are crystallographically identical. Crystals were grown from acid, alkaline, and neutral solutions exposed to light, heat, and air. The amber-coloured crystals contain colloidal ferric hydroxide. L. J. S.

RK (J. M.). *Induced color in crystals by deuteron bombardment.* Physical Rev. (Amer. Phys. Soc.), 1942, vol. 62, pp. 80–81.

— *Note on induced color in diamonds.* Ibid., p. 494.

Alkali halides, fluorite, quartz, and diamond showed changes in colour when nbarded with deuterons in the cyclotron. Yellow diamond changed to green the surface, and regained its original colour on heating at 900°. L. J. S.

OROVSKAYA (V. N.) Флоровская (В. Н.). *A new luminescence method for establishing the bituminous nature of rocks.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 31, pp. 359–360.

Various organic minerals were tested for fluorescence in ultra-violet rays 2200–4000 Å.). Of the salts of organic acids only mellite responds, giving a ght blue-violet with short waves. Amber, resins, and ozokerites fluoresce h long waves. Asphalt and bitumens also give characteristic colours. The inescence is made more vivid if the mineral is moistened with chloroform or nzene, when $< 0{\cdot}01$ % of bitumen can be detected in a rock. L. J. S.

LKOV (V. G.) & SVERDLOV (Z. M.) Мелков (В. Г.) и Свердлов (З. М.). *A luminescence method for detecting uranium minerals and ores.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 31, pp. 361–362.

Pitchblende when sprayed with acids (acetic the most convenient) forms com-unds which fluoresce in short ultra-violet rays. With the uranium vanadates sedimentary rocks a stronger acid is used. A portable apparatus for use lerground is being made. L. J. S.

NCAN (Frank). *Unusual calcite crystals of the old Mariposa mine.* Rocks and Minerals, Peekskill, N.Y., 1944, vol. 19, pp. 303–305.

Transparent golden crystals of a complex type have been found at the Mariposa cksilver mine, near Terlingua, Texas. These crystals, which show a phantom ucture, occur with manganese ore and fluoresce in shades of yellow and green. ite calcite from the same locality shows a strong white phosphorescence as l as fluorescence, and pink calcite shows blue phosphorescence. Fluorescence thought to be influenced by associated manganese ores, but it is now con-red that both fluorescence and phosphorescence may be due to accompanying rcury minerals. J. M. S.

Instruments and Apparatus

FRIES (Charles D.). *A double centrifuge tube for the separation of soil minerals by means of heavy liquids.* Soil Sci., 1941, vol. 52, pp. 167–170, 1 pl.

double centrifuge tube made of pyrex glass consists of an inner tube with nall hole at the bottom resting inside an outer tube which is first filled to a n mark with heavy liquid. After the mineral sample is weighed into the r tube the apparatus is placed in vacuo to remove occluded air and then rifuged. The lighter fraction is withdrawn by plugging the top of the inner e with a rubber stopper carrying a glass tube, the end of which is sealed with finger when lifting out the inner tube. This enables a complete separation he light and heavy fractions, which are then dried and weighed separately. ults are given for fine sand fractions (0·10–0·05 mm.) of soils. F. A. B.

Fairbairn (H. W.). *Gelatincoated slides for refractive index immersion mou* Amer. Min., 1943, vol. 28, pp. 396–397.

Microscope slides are coated with a film of gelatin. This is moistened wi drop of water and the grains or powdered mineral sprinkled on. When dr the particles are held into position (without being completely embedded) a can be tested in a series of oils. L. J. S.

Foster (Wilder D.). *Interference figures with greater contrast.* Amer. Min., 19 vol. 27, pp. 57–58.

A diaphragm between the polarizer and the source of light increases the cont between an interference-figure and the background. L. J. S.

Fisher (D. Jerome). *Making crystal models.* Amer. Min., 1941, vol. 26, pp. 71 726, 9 figs.; 1943, vol. 28, p. 54.

Instructions for students are given for making nets to be folded into cardbo models of crystals. The directions of the intersecting edges of faces are obtai from the gnomonic projection, using the euthygraphic projection of a face guide line. The second note gives a simpler method of obtaining the length the various edges. [M.A. 4–7.] L. J. S.

Frederickson (A. F.). *Additional notes on the final grinding of petrograph thin sections.* Amer. Min., 1942, vol. 27, pp. 58–60.

Hints are given for correcting a wedge-shaped slice or one thicker in the cent than at the edges. [M.A. 8–294.] L. J. S.

Dollar (A. T. J.). *Laminar moulds in cellulose acetate for the study of rock a mineral structures.* Geol. Mag. Hertford, 1942, vol. 79, pp. 253–255, 1 pl.

—— *Recording low relief in metallic surfaces by cellulose acetate moulds.* Natur London, 1943, vol. 152, p. 248, 1 fig.

A description of the application of the cellulose acetate 'peel' method, widel used by palaeontologists, to the study of rock structures. Moulds from groun and etched rock surfaces show clearly the boundaries of the mineral constituent etch-figures, cleavages, &c., and in some cases, by previously dyeing the prepare rock, a peel can be obtained differentiating the mineral constituents by colou The illustrations show a granite and a meteoritic iron. C. F. D.

Dollar (A. T. J.). *Cellulose acetate mounts for rock and mineral fragment* Nature, London, 1944, vol. 153, p. 226.

The mineral powder or heavy concentrate is sprinkled on cellulose acetate wit tetrachloroethane and 'cerric thinner' on a sheet of glass; when dry, the fil is stripped off for examination and permanent record. L. J. S.

Buerger (M. J.), Buerger (Newton W.), & Chesley (Frank G.). *Apparatu for making X-ray powder photographs at controlled, elevated temperature* Amer. Min., 1943, vol. 28, pp. 285–302, 11 figs.

The camera and the tiny furnace are separate units which can be slipped o as sleeves over the specimen holder. It is thus possible to remove the camer and develop the film during the process of heating. In the furnace cylinders o aluminium foil serve as radiation barriers, and these having much less hea

acity than an insulating barrier allow rapid heating. The temperature is brated by means of substances having polymorphic transformations. The paratus has been used up to 600° and is suited to higher temperatures. The ting unit has also been adapted to the Weissenberg camera. L. J. S.

OD (R. G.) & WILLIAMS (C.). *A simple Weissenberg camera.* Journ. Sci. Instr., 1944, vol. 21, pp. 141–142, 3 figs.

detailed description of apparatus for taking X-ray rotation and moving- photographs of single crystals. F. A. B.

ARER (J.). *X-ray powder diffraction camera.* Journ. Sci. Instr., 1944, vol. 21, pp. 198–200, 2 figs.

he camera (5·7 cm. diameter) has been designed for the rapid production of rge number of powder photographs by relatively unskilled workers and is mmended for the study of soil colloids. The slit collimator consisting of a brass block has one face 0·2 mm. from the axis of the camera and to this face stened a flat celluloid powder container. A powder photograph of bentonite en in 15 minutes with this camera is reproduced. F. A. B.

VEY (Wheeler P.), SMITH (F. Raymond), & HARDING (Samuel W.). *An automatic X-ray diffraction apparatus.* Rev. Sci. Inst., 1944, vol. 15, pp. 37–45, 13 figs.

pparatus is described in detail which records automatically in the form of an d graph on a moving strip of co-ordinate paper diffraction patterns of crystals powders. The graphs give a plot of X-ray intensity of diffraction, measured a quantum counter, against angle of diffraction. F. A. B.

NS (R. C.) & PEISER (H. S.). *A machine for the computation of structure factors.* Proc. Physical Soc. London, 1942, vol. 54, pp. 457–462, 2 pls.

machine, constructed almost entirely of meccano parts, evaluates mechani- y the expression $2f\cos(hx+ky)$ giving the structure factor of two atoms related a centre of symmetry. Its more general application to the evaluation of cture factors is discussed. F. A. B.

Mathematical Crystallography

OGOWITZ (Ulrich). *Herleitung aller homogenen nicht kubischen Kugelpackungen.* Zeits. Krist., 1943, vol. 105, pp. 23–52, 16 figs.

n exhaustive investigation into the possible modes of arranging spheres in non-cubic space-groups; 46 anorthic, 729 monoclinic, and 2087 orthorhombic; hese 681 are possible ways of packing spheres. F. A. B.

LMORE (Sidney). *Open packing of spheres.* Nature, London, 1944, vol. 154, p. 708, 1 fig.

n arrangement of equal spheres in which each one is in contact with six ers, and the density of the structure is 0·370. [M.A. 5–342.] L. J. S.

Eisenschitz (R.). *Matrix theory of correlations in a lattice. Parts I and* Proc. Roy. Soc. London, Ser. A, 1944, vol. 182, pp. 244–259, 260–269, 5 fi

The statistical mechanics of some crystalline systems may be reduced statistical correlations between objects which are the unit cells of a fictiti lattice. By certain postulates matrices are implicitly defined such that t probability distribution for a chain of cells is found by forming the powers a matrix. The theory is applied to the order-disorder equilibrium like known to exist in β-brass and to a treatment of the effect of thermal expan upon the specific heat of that alloy. F. A. B.

Wolfe (C. W.). *Hexagonal zone symbols and transformation formulae.* Am Min., 1944, vol. 29, pp. 49–54, 4 figs.

Zone symbols may be obtained by the usual cross-multiplication when t four-index face symbols are reduced to three by adding a number to h, k, a to make one of them zero. For a change in the c-axis the transformation form is written as $1000/0100/0010/000n$. An error in Min. Mag. **22**–283 is pointed o [M.A. **2**–108.] L. J. S.

Ramsdell (Lewis S.). *The gnomonic projection in the hexagonal system.* Amer Min., 1942, vol. 27, pp. 819–823, 2 figs.

From 0-level reciprocal lattices derived from gnomonic projections in t settings 'G1' and 'G2' of Goldschmidt the two hexagonal unit cells are draw That based on 'G2' is three times the size of that based on the convention orientation ('G1'), and the axial ratio is different. The continued use of th 'G2' setting for either hexagonal or rhombohedral crystals is deprecated, havi given rise to much confusion [and many errors in the literature]. L. J. S.

Decker (Beulah Field). *Vector formulas for identification of twinned lattice* Amer. Min., 1944, vol. **29**, pp. 226–234, 4 figs.

Vector formulae are derived to give the reciprocal lattice vectors for the twi of lattice planes by reflection, rotation, or inversion. Transformation equatio for vectors in terms of spherical co-ordinates are derived and examples are give of twinning in the cubic and hexagonal systems. F. A. B.

Ledermann (Walter). *Asymptotic formulae relating to the physical theory crystals.* Proc. Roy. Soc. London, Ser. A, 1944, vol. 182, pp. 362–377, 1 f

Born's theory of the lattice dynamics of crystals involves approximatio which under certain conditions are found to be justified. A rigorous mathemati examination shows that the boundary particles of a lattice have only a negligib influence on the density of frequencies, providing needle or lamellar shaped crysta are excluded. [M.A. **8**–361.] F. A. B.

Donnay (J. D. H.). *Rules for the conventional orientation of crystals.* Ame Min., 1943, vol. 28, pp. 313–328, 4 figs.

The following rules are suggested for use in all systematic descriptions, eith morphological or structural. (1) The cell chosen to express the lattice should b the smallest cell having full lattice symmetry. (2) The axial cross should be righ handed. (3) Cell edges $c < a < b$. (4) Axial angles α and β in the triclinic syste

β in the monoclinic system all should be obtuse. These are 'probably as good ny other arbitrary set'. Examples of different settings are given for sylvanite, gar, and lorandite. [M.A. **4**–337; **6**–80; **7**–163; **8**–344.] L. J. S.

INAY (J. D. H.). *Resetting a triclinic unit-cell in the conventional orientation.* Amer. Min., 1943, vol. 28, pp. 507–511.

ransformation matrices are given, and the elements of triclinic crystals of ral minerals and artificial compounds are recalculated in accordance with rules given in the preceding abstract. L. J. S.

L (James Forbes). *Morphology of mechanical twinning in crystals.* Amer. Min., 1941, vol. 26, pp. 247–261, 8 figs.

general account is given of twin-gliding, which may be described as a process mple shear. Calcite is taken as the type example, although such mechanical ning has been produced in at least fifty different minerals and is of importance etals. Formulae are given relating the indices of any face before and after ning, but these cannot be used as a direct solution for the elements of the ning deformation. A direct graphic solution is, however, presented.
L. J. S.

Miscellaneous

Y (Joseph M.). *Minor chemical elements in fluorites from Jamestown, Colorado.* Amer. Min., 1942, vol. 27, pp. 769–775, 1 fig.

uorite from four mines at varying distances from the parent stock of granite quartz-monzonite were examined spectrographically and 20 minor elements d. The most abundant are Sr, Ba, Fe, Yt, Cu, Mg, Al, Si, which probably titute Ca in the ionic fluorite structure. The oldest fluorite (nearest the parent t) is the most impure and the youngest the purest. No correlation was ble between the minor elements and radioactivity, fluorescence, or wall-rock e veins. [M.A. **8**–324.] L. J. S.

PF (Adolph). *Ludwigite from Colorado Gulch, near Helena, Montana.* Amer. Min., 1942, vol. 27, pp. 824–825.

rge quantities of radially fibrous ludwigite occur with magnetite in dolomite limestone close to the contact with quartz-monzonite. The low sp. gr. 3·70 ates that it is near the magnesian end of the series; ludwigite from other ities gave 3·62–3·97. L. J. S.

N (Rolf). *Thuringit från Skälsta i Håtuna socken.* Geol. För. Förh. Stockholm, 1942, vol. 64, pp. 341–343, 1 fig.

uringite (β 1·657) from a graphite deposit in pegmatite gave SiO_2 29·6, Al_2O_3 Fe_2O_3 13·7, FeO 24·0, MgO 3·3, CaO 0·7, H_2O+ 9·3. A thermal analysis is given. L. J. S.

DOCH (Joseph). *Crystallography of hureaulite.* Amer. Min., 1943, vol. 28, pp. 19–24, 1 fig.

all (1 mm.), colourless to amber-coloured crystals of hureaulite, recently ted with other phosphates at Stewart mine, Pala, California, are elongated

along the *c*-axis and tabular on (100) or of prismatic habit. Goniometric measurements gave $a:b:c = 1{\cdot}9307:1:1{\cdot}0470$, β 83° 20′, and nine new (some doubtful) forms. An angle table of all known forms is given. X-ray photographs gave *a* 17·42, *b* 9·12, *c* 9·50 Å., probable space-group C_{2h}^{4}, with four molecules in the unit cell. The material contains only 0·1% Fe; hardness 3–4. L. J. S.

Palache (Charles), Richmond (W. E.), & Wolfe (C. W.). *On amblygonite*. *Part 1. Amblygonite from Hebron, Maine* (W. E. Richmond & C. W. Wolfe). *Part 2. Amblygonite from Newry, Maine* (Charles Palache). Amer. Min., 1943, vol. 28, pp. 39–53, 9 figs.

Goniometric measurements of small (½–3 mm.), white, translucent to transparent crystals from a pocket in pegmatite at Hebron gave in a new orientation $a:b:c = 0{\cdot}7255:1:0{\cdot}7028$, α 111° 59½′, β 97° 46½′, γ 68° 16½′, with two new forms, twinning on $(\bar{1}\bar{1}1)$ and (111), and cleavages (100), (110), (011), and (001). X-ray measurements gave *a* 5·18, *b* 7·11, *c* 5·03 Å., with $2[LiAlPO_4(OH,F)]$ in the unit cell; sp. gr. 3·05. The optical orientation was determined, and an angle table of the known forms of amblygonite is given. Spectacular crystals, up to 11 cm., have been found in pockets in pegmatite in a new felspar pit at Newry, on which eight new forms are noted. L. J. S.

Denning (Reynolds M.). *Aluminum-bearing scorodite from Hobart Butte, Oregon*. Amer. Min., 1943, vol. 28, pp. 55–57, 1 fig.

Cellular colloform crusts of pale-green scorodite occur in an altered andesitic tuff. The refractive indices, α 1·712, $\gamma \parallel$ fibre 1·728, are low. Assuming mean *n* 1·7 and 1·577 for the Fe and Al end-members, Al_2O_3 is calculated as 7·1%. L. J. S.

Chapman (Carleton A.). *Large magnesia-rich triphylite crystals in pegmatite*. Amer. Min., 1943, vol. 28, pp. 90–98, 4 figs.

Large (up to 10 cm.) rough crystals occur in quartz-albite-pegmatite at Newport, New Hampshire. Six forms, (121)? probably new [Dana's axes], were identified with the contact goniometer. The material is green and nearly transparent when unfractured; α 1·675, β 1·684, γ 1·685, 2V 25°, negative, sp. gr. 3·44, H. . Analysis by J. M. Lindgren shows high MgO and low MnO; P_2O_5 46·03, SiO_2 0·3 Al_2O_3 3·19, Fe_2O_3 0·00, FeO 32·93, MnO 3·11, MgO 7·38, CaO 0·00, Li_2O 8·3 Na_2O 1·05, K_2O 0·45, H_2O+ 0·57, HO_2- 0·20 = 103·60. These data do not fit plots of composition against optical properties or sp. gr., no doubt because of t high MgO. Data are not available for a $LiFePO_4$–$LiMnPO_4$–$LiMgPO_4$ plo The mineral alters to vivianite, which gave α 1·580, β 1·602, γ 1·632, 2V about 8 positive. L. J. S.

Dodge (Daniel V.). *Identification of the opaque minerals by electrochemical methods*. Amer. Min., 1943, vol. 28, pp. 103–109, 1 fig.

Some minerals are not acted upon by the usual spot reagents on polished surfaces. Action may be promoted by passing a direct or alternating current of 4– volts through the drop, and the liquid can then be used for micro-chemical tests. Results are recorded for cassiterite, chalcopyrite, chromite, franklinite, haematite, ilmenite, magnetite, rutile, and blende. [M.A. 6–377.] L. J. S.

ILINSON (W. Harold). *Occurrence of sodic scapolite at Falls of French Creek, Pennsylvania.* Amer. Min., 1943, vol. 28, pp. 110–114, 3 figs.

ong-prismatic (up to $4 \times \frac{1}{2}$ cm.) crystals of marialite, colourless and glassy n fresh, becoming cloudy on exposure, occur with prehnite, heulandite, ene, chlorite, and apatite in narrow (5 cm.) veins cutting across a diabase sill. ilar albitic veins in the same sill were derived from residual liquors from the ing basaltic magma. The crystals show repeated zoning with ϵ 1·542, but ω in- sing from 1·549 to 1·552 in the outer zones. Analysis of all zones, SiO_2 57·01, O_3 23·85, CaO 5·00, Na_2O 8·42, K_2O 1·24, Cl 2·72, ign. 1·75, corresponds to $_8Me_{22}KMe_{10}$. When $Ma_{70}Me_{30}$ was reached the solutions with increasing calcium osited prehnite, often as a capping on the scapolite. L. J. S.

ST (A.). *Large and small garnets from Fort Wrangell, Alaska.* Amer. Min., 1943, vol. 28, pp. 233–245, 4 figs.

he habit and crystal-forms of different garnets are noted. On the larger tals of almandine in mica-schist from Fort Wrangell (110) predominates, while he smaller crystals (211) predominates. L. J. S.

JNER (John W.) & STAUFFER (C. R.). *A unique occurrence of bobierrite, $Mg_3(PO_4)_2.8H_2O$.* Amer. Min., 1943, vol. 28, pp. 339–340.

hin (1–2 mm.) layers of well-crystallized and fibrous bobierrite were found veen the shell and core of a fossil elephant tusk from gravel and clay at erton, Pipestone Co., Minnesota. Sp. gr. 2·2, α 1·510, β 1·520, γ 1·543, $\beta = b$, $= 28°$. L. J. S.

INELL (James H.). *Factors influencing the distribution of the elements.* Amer. Min., 1943, vol. 28, pp. 605–613.

Discussion on the order of abundance of elements in the earth's crust as in- nced by ionic size and charge. [M.A. 2–389, 558; 3–181, 261; 7–165, 166.] L. J. S.

HA (Aristides N. da) & COSTA (Odélio). *Um mineral do grupo ambligonita- montebrasita de Mogí das Cruzes, São Paulo.* Notas Prelim. Div. Geol. Min. Brasil, 1941, no. 22, 8 pp., 2 figs.

Montebrasite, a mineral new to Brazil, was found in kaolin from the weathering ranite and pegmatite, as massive white material with a violet tinge, perfect vage, and polysynthetic twinning. Sp. gr. 2·89, H. 6, β about 1·614, $\gamma - \alpha$ 3, 2V 80°. Analysis, P_2O_5 46·70, Al_2O_3 35·80, Li_2O 8·80, Na_2O 1·41, SiO_2 0·48, 27, H_2O 4·54, TiO_2, Fe_2O_3, MgO, CaO, K_2O traces, agrees with $LiAl(OH,F)PO_4$. O. L. J. S.

UKHROV (F. V.) Чухров (Ф. В.). К минералогии и геохимии бария в осадоч- ных породах в связи с изучением Керченских баритов.—*On the mineralogy and geochemistry of barium in the sedimentary rocks in connection with the study of the Kertch barites.* Изв. Акад. Наук СССР, Сер. Геол. (Bull. Acad. Sci. URSS, Sér. Géol.), 1937, no. 3, pp. 531–561 (Russian), 562–563 (English), 8 figs.

aryte is found as concretions, as infillings or replacements of calcareous fossils, as irregular crystal-aggregates in the Pliocene oolitic iron-ores of the Kerch insula. The mineral is especially abundant in association with the more

manganiferous ores. It is postulated that the baryte was precipitated in colloid form along with psilomelane and wad, later becoming metacolloidal or cryp crystalline. Such cryptocrystalline baryte characteristically occurs as oolit pisoliths, concretions, septaria, &c., as secretions in the cement between the c ooliths, and in fissures formed on dehydration of the primary colloid sedim Various other problems of the geochemistry of barium are discussed and a g bibliography is given. [M.A. **6**–296.] C. F. D.

[Tzinzerling (E. V.)] Цинзерлинг (E. B.) Zinserling (E. V.). *Quartz twinn control under $\alpha \rightarrow \beta$ conversion.* Compt. Rend. (Doklady) Acad. Sci. URS 1941, vol. 33, pp. 365–367, 3 figs.

Plates of quartz showing scattered areas of Dauphiné twinning are heated 600° C. and very slowly cooled through the interval 580–550°. The large cen area then consists of a single crystal with twinned portions only along the ed of the plate. L. J. S.

[Tzinzerling (E. V.) & Lemmlein (G. G.)] Цинзерлинг (E. B.) и Леммлей (Г. Г.) Zinserling (E. V.) and Laemmlein (G. G.). *Conversion of a negati quartz rhombohedron into a positive one as a result of $\beta \rightarrow \alpha \rightarrow \beta$ transformatio* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941, vol. 33, pp. 419–420, 1 fig

Plates ($\frac{1}{2}$ mm. thick) cut parallel to the positive (r) and negative (z) rhombo hedra of a colourless quartz crystal both showed after the $\beta \rightarrow \alpha \rightarrow \beta$ trans formation a larger central area of r surrounded by a twinned border of z. Wit plates cut from smoky quartz or crystals that are susceptible to colouring b X-rays there is no such twinning and change from z to r, the impurities presen evidently helping to preserve the original orientation. [M.A. **9**–135.] L. J. S.

[Tzinzerling (E. V.)] Цинзерлинг (E. B.) Zinserling (E. V.). *Twinning o quartz in the electric field.* Compt. Rend. (Doklady) Acad. Sci. URSS, 1941 vol. 33, pp. 421–423, 4 figs.

Plates (1 mm. thick) of quartz heated at 570° C. and placed between electrodes with a continuous potential of 400 volts for $\frac{1}{2}$–$1\frac{1}{2}$ hours showed twinning and cracks along the electric axes of the quartz in places where there had been an electric discharge. Near the edges of the plate cleavage cracks (0001) were formed. Similar results were obtained at room-temperature with 1500 volts.

L. J. S.

Jensen (Einar). *Om dannelsen av mineralet trådsølv.* [On the formation of the mineral wire-silver.] Det 5. Nordiske Kemikermøde, København 3.–7. Juli 1939, København, 1940, p. 193.

When silver is precipitated in the presence of antimony (either solid or in solution) it takes a wiry form. At Kongsberg, Norway, it has been formed by migration of Ag from argenite in the presence of Sb‴ or Cu″ below 100°.

L. J. S.

Bianchini (Gino). *Su di un' aftitalite cupro-manganesifera vesuviana.* Rend. Accad. Sci. Fis. Mat. Napoli, 1937, ser. 4, vol. 7, pp. 43–47.

Four analyses of colourless and greenish-blue, granular and columnar aphthitalite gave SO_4 60·18–61·22, Na 13·35–15·59, K 22·46–25·73, Mn 0·45–0·61, Cu 0·05–1·13, Cl 0–0·16; sp. gr. 2·698–2·701. L. J. S.

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